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THE PALATE OF CIVILIZED MAN AND ITS INFLUENCE ON AGRICULTURE.*

BY

DAVID FAIRCHILD, Sc.D.,

Agricultural Explorer in Charge, Office of Foreign Seed and Plant Introduction, U. S. Department of Agriculture.

THE expression, "I do not like it," is the stone wall which blocks or hinders every attempt to introduce a new food. The purpose of the discussion this evening is to analyze the situation created by the vagaries of taste in foods and ascertain if these vagaries are not responsible for a larger part in agriculture than is commonly supposed—a controlling factor, even, in the cultivation of vast areas of land. My position in the Department of Agriculture, that of investigating the food plants of the world, to find out which could be introduced and grown in America, has perhaps permitted me to gain a bird's-eye view of the situation and warrants my making certain generalizations which grow out of twenty years of foreign and domestic correspondence and travel.

It seems to me that the present era is one of tremendous change and immense possibilities in these matters of food, and that the time is at hand when full discussion of taste in foods is opportune. The war is rapidly changing the trade routes of the world, and the Oriental tropics are brought closer to us than ever before by the lines of direct steamers through the Panama

* Presented at a meeting of the Section of Physics and Chemistry held Thursday, October 25, 1917.

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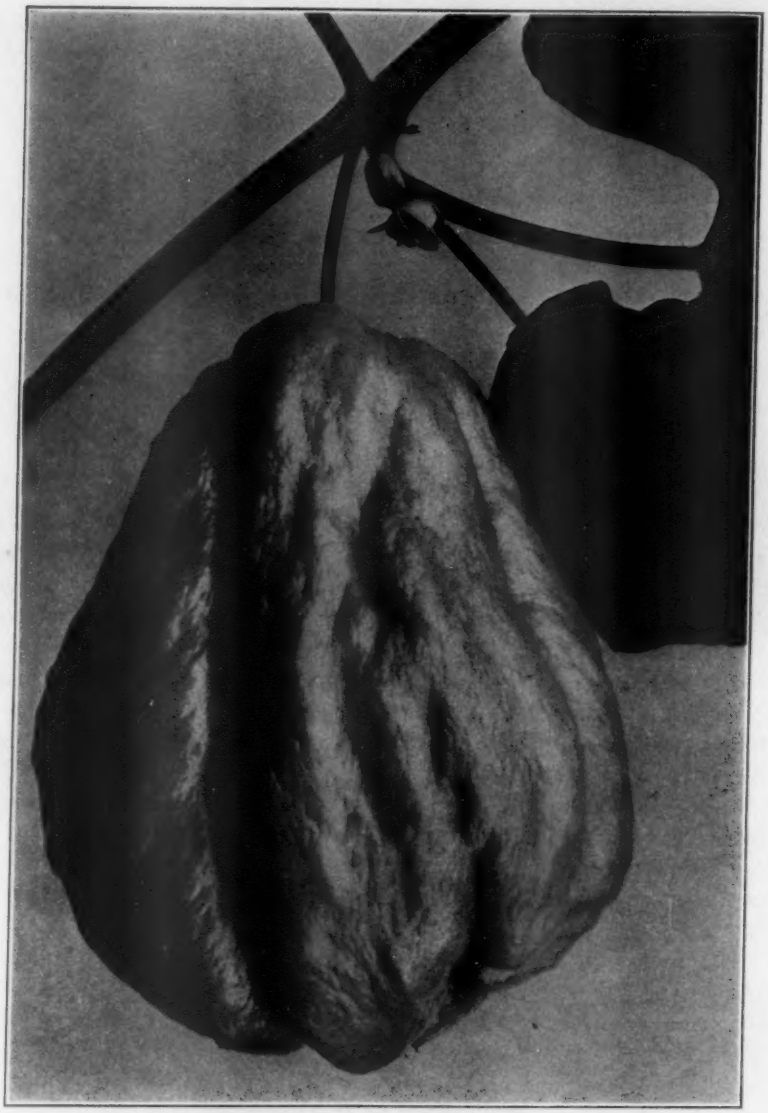


FRUIT OF THE CHAYOTE, A GUATEMALAN VEGETABLE (*Chayota edulis*). (Full size.)

This fruit, though with no pronounced flavor, has a remarkable texture and can be used in a large variety of ways. It is more delicate than a squash or cucumber. It is a staple vegetable in those tropical countries where it is grown, and is now being cultivated in Louisiana and Florida.

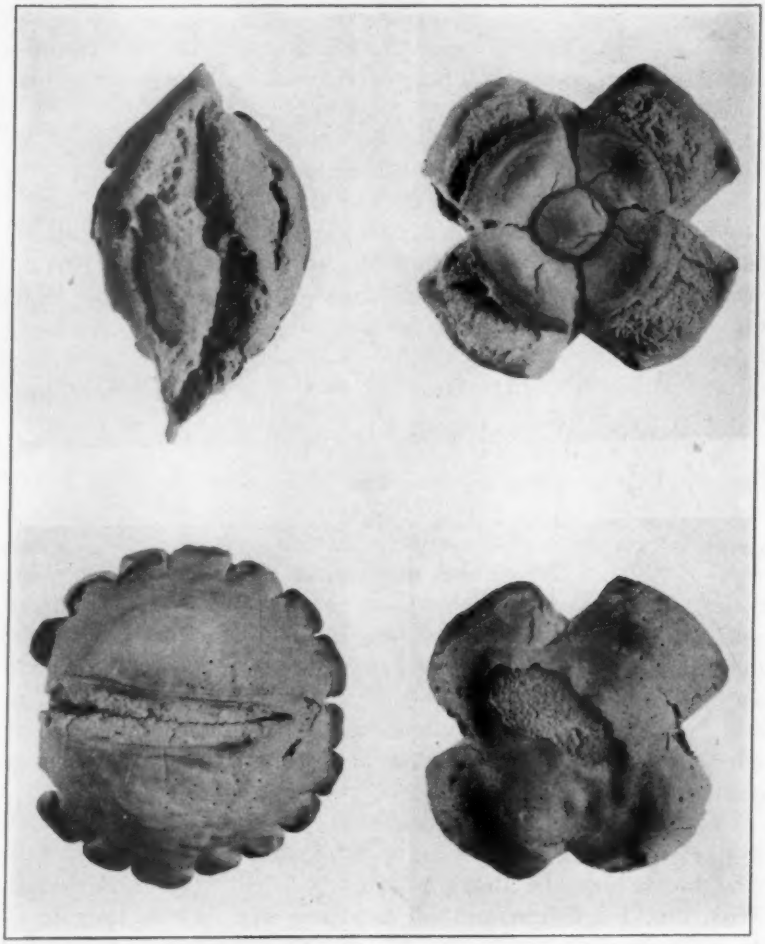
Canal. New York is now in direct touch with Java and Singapore, and a new direct line to Chile and Peru has just been opened. Sanitation, the discovery of the yellow fever mosquito, the advent of good roads and automobiles, have made farm life in the tropics a very different thing from what it was a generation ago.

We have the spectacle of hundreds of millions of people studying as they never did before the food supply of the whole world with reference to their particular contribution to it as a world-problem, not, as in former years, largely as a local question. One can hear in one's imagination the food talk of the Malay rice growers as they wade knee deep in the mud of the paddy fields of the Philippines. The llama drivers on the Cordilleras of the Andes, the *beche de mer* fishers off Thursday Island, the vanilla vine growers in the Seychelles, the banana plantation darkies in Jamaica, the Chinese tea pickers on the river of the nine windings, the Labrador fishermen, the New Zealand sheep rangers, the Liberian coast boys in their oil palm forests, and the Fijian coconut growers in their atolls in the Pacific—all are more or less affected by the great war and its effect upon the price of food.

Could a Southern planter or a Western farmer have imagined that the Belgians would refuse to eat his corn or that the British would even under the pressure of war prices buy corn-meal with great reluctance, and the reason be that "corn-meal is chicken food"? The soldiers' likes and dislikes in food have no doubt restricted and hampered the prosecution of the war. Blackberry jam formed an integral part of the ration of our miniature standing army, but it is hardly to be expected that it will be available for the million men soon to be in the field. Now, while the events and facts are fresh in every one's mind, it may be well to consider whether it may not be easier to change our minds than to change our agriculture.

Consider the corn situation to-day and its bearing upon the gigantic problem before us of feeding starving Europe. When I first heard that the Belgians refused to eat corn, and that the Irish and English would eat anything else before they would touch it, my first impulse was to insist that they ought to be made to eat it. Edward Eyre Hunt, the author of "War Bread," explained and made it entirely clear to me that a shocked and outraged people, wrought up and nervous to a high degree as a re-

sult of the treatment they have received, is in no mental attitude to learn to like a new food. The task of education would have been too long and more expensive than the shifting of our own ménu at home, and in the meantime would have cost many thousands of lives. Resort was made to the use of different names



LOAVES OF SPANISH DURUM WHEAT BREAD.

In southern Spain the wheat bread is very different from ours. It is hard and yellowish and has a substance to it which ours does not have—yet the average American would not like it any better than the Spanish peasant likes our soft, spongy bread, even though it is quite as nutritious. It is made of a different species of wheat from that which we grew previous to 1898—the durum or macaroni wheat.

for corn and concealment of it in war bread with three parts of white flour. Sir Horace Plunkett informed me that unfortunately his people had grown up to look upon corn as hog and chicken food, and that this prejudice was extremely difficult to overcome, but that high prices would in time force them to eat it. One of the British commissioners to this country remarked, last spring, to one of our Southern ladies, "Madam, I wish you could send us a hundred darky cooks to teach our people how to cook corn."

The Food Administration, in its pamphlet on "Graphic Exhibits," suggests a poster explanatory of why we cannot send corn abroad. On the one side is a darky cook with apron held out to Uncle Sam, begging for ears of corn; on the other, a French baker shrugging his shoulders and saying, "I don't know how to use it."

Not to like a food which has been the staple of peoples for thousands of years and to-day is produced by the thousand million bushels and feeds hundreds of millions of people seems to us who like it a strange, incomprehensible spectacle. Yet it is no stranger than that of the American people and their indifference to that other great cereal, rice, which is produced in larger amounts than any other cereal in the world and forms the staff of life of hundreds of millions of civilized peoples.

It is said that Europe is dependent upon the wheat loaf, and the bakeries of that country are ill suited to utilize corn. We are sometimes inclined to insist that they should break away from the exclusive use of the wheat loaf and learn to make corn bread and corn cakes—yet we have not yet learned how to cook rice properly, and complain of its insipid character, which must be an attitude hard for our Oriental neighbors to understand. This indifference toward rice, of which staple we even now consume only the insignificant quantity of seven pounds per capita, has led to the abandonment of the fertile rice fields of the Carolinas, and to-day efforts are being made to find some paying crop to take its place there, because our meagre demands have been met until very recently by the California and Texas rice areas recently developed.

I find that most people whom I meet have never stopped to think whether what they eat makes any difference to any one else. They drink their cup of coffee without seeing the vast red

clay hills of Brazil covered with square miles of coffee trees loaded with red berries. They do not stop to realize that their preference for coffee instead of for cocoa or tea means that their money is contributing to the great civilization of southern Brazil

A BLANCHED SHOOT OF UDO.

Unlike the asparagus or celery, the blanched shoot of udo has no objectionable fibres in it. It is crisp clear down to the ground and has a characteristic flavor the like for which, like for almost all flavors worth while, has to be acquired. The author looks forward to the season for udo as he does toward the asparagus or rhubarb season.

instead of to the tropical cacao plantation life of Venezuela or Trinidad or the beautiful hillside farm life of the tea plantations of the Orient. Whether they drink Oolong or green or black tea seems a very small difference to them, but in the aggregate it means the success or failure of vast plantations with thousands of tea pickers in China, Japan, or Ceylon.

Can the fact be established that, in the past, fashion in foods, a like for a food or a positive dislike, or a mere indifference toward it has brought about the cultivation of the plant, checked or stopped its cultivation, or accelerated its widespread cultivation? If it can, there will be no longer doubt that the factor is important, and the question of its careful scientific investigation is one worthy of serious consideration by the scientific bureaus and laboratories of the country and our great educational institutions as well.

The origin of many cultivated plants dates back beyond the dawn of history, and many of them have become so almost universally grown that no traditions even are left to mark the struggle they had to gain popular favor. Others, again, are so new that they are at the present time fighting for a place on the ménu.

The wheat plant and the loaf of bread made from its kernels are universally liked. There is no race of people which does not like it. Yet it is a fact that the delicious hard bread of Spain and Russia, made from the durum wheat, a distinct species from our wheat, is not popular to-day in this country, and macaroni, the most popular form in which wheat is used in Italy, has, until recently, been little appreciated in America. These two facts hindered the development of the durum wheats when they were first introduced into this country in the nineties. If it had not been possible to export wheat to Italy for macaroni making, there is serious doubt whether we should now have had the vast fields of it in Kansas, Minnesota, and the Dakotas. Millers had to remake their mills in order to grind the harder kernels, and bakers had to learn to mix it with softer wheats.

The oat is cultivated successfully in Hokkaido, the north island of Japan, but not for human food. It is used for the purpose of feeding to cattle in that island, and is imported in the south islands for the use of military horses, whereas we devote over thirty million acres to its culture. Oatmeal is a staple breakfast dish in millions of American homes.

Buckwheat griddle cakes form the great breakfast dish in parts of New York and Pennsylvania, and are indispensable now to every city restaurant. To supply this fashion, which just after the Civil War was apparently at its height, we planted a

A HILL OF BLANCHED UDO (*Aralia cordata*).

Every spring, before the hill of udo starts into growth, it is mounded over with light soil to a height of a foot or two, or a drain tile closed with cement at one end may be substituted. Under this soil or in the darkness of the closed tile the tender shoots grow up perfectly white. They should not be allowed to become green, as this gives them a strong flavor. They are tender from top to bottom and absolutely stringless.

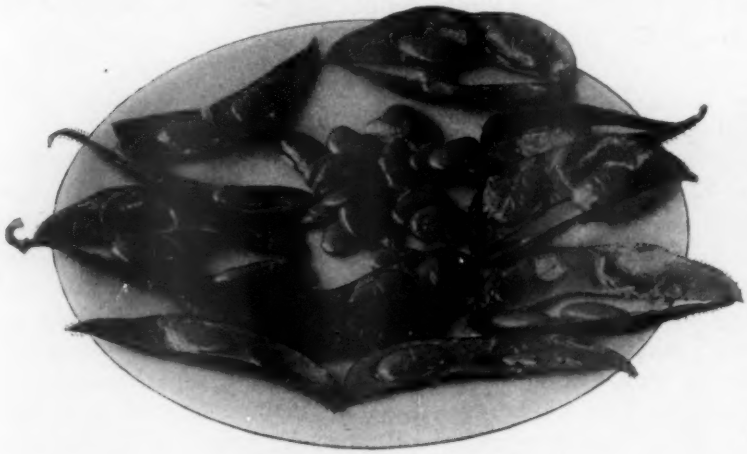
million and a quarter acres of buckwheat. To-day this has dwindled to three-quarters of a million. The Japanese, on their crowded areas, grew, in 1906, nearly 400,000 acres of buckwheat, yet I doubt if any Japanese who has not been in America knows the good qualities of buckwheat griddle cakes, and I am sure no New York or Pennsylvania farmer has ever tasted the buckwheat macaroni, which is the way in which the Japanese eat buckwheat. These two fashions have no relation whatever to each other, and yet each is largely responsible for the areas now under buckwheat cultivation in these two countries. They are both fashions that might die out and force buckwheat out of cultivation.

Examples could be multiplied almost indefinitely to show that just as what we like determines what we grow individually, so it does collectively.

The European grape was unsuccessful in eastern America and equally so in Japan. We originated the American grape varieties from our wild species and fortunately learned to be fond of their musky flavor before California began growing the European grape. This fondness for the Concord and Niagara and other American sorts has built up the Hammondsport grape industry along the lakes of western New York. Europeans, although they use the root of our American grape because it is resistant to the *Phylloxera* disease of their vine, scorn to eat the fruit, and there is no culture of American grapes in Europe, even though they are more resistant to disease.

The Honey Dew melon came in a few years ago and is now a rival of the grape-fruit on our tables, and grape-fruit growers fear it. There was a time when the orange growers of Riverside would have been glad if Easterners ate only navel oranges. They were not vitally interested in the exploitation of any other variety or any other fruit crop. The present production of navel oranges in California approximates 27,000 carloads a year, or about two-thirds of the total orange shipments of the state. Yet one of the principal growers of Riverside has just reported to me that the recent hot wave almost completely ruined the navel orange crop this year, and he wants to grow something else. The fixed fashion of eating oranges and grape-fruit makes people keep on buying them regardless of cost, though the freeze last year cut the Florida crop to a quarter of normal and the drouth cut the California navels out entirely.

How did seaweeds and candied grasshoppers come into use in Japan, and fried rhinoceros hide in Africa, and powdered deer horns in China, and pickled pigs' feet in Germany, and mouldy cheese with skippers in it in England, and snails and frogs' legs in France, and grasshoppers, fried and reduced to a meal, in Arabia, and snakes and lizards among the North American Indians, and the octopus among the Neapolitans, and wood-grubs among the New Zealand Maoris, and larks' tongues and eels fed on the flesh of slaves in Rome, and caviar, the eggs of the Volga sturgeon, among the Russians, and rats and mice and



THE "DOVE-KILLER" SOY BEAN.

Some kinds of soy beans, such as the "Dove-killer," are delicious when gathered green, boiled in their pods in salted water, and then shelled. As shown by Mr. Morse, of the Department of Agriculture, they are quite as attractive as lima beans and are even more delicate in flavor, and, as the vines require no poles to grow on, they are easier of cultivation than the lima bean.

dogs and cats by the Chinese, and human flesh by the Fiji Islanders? Is it reasonable to suppose that these customs were acquired in some mysterious evolutionary way? Is it not highly probable that these foods came into vogue just as we know coffee and tea and the potato and tobacco and chocolate have come to be fashionable to-day in European and American countries, through the encouragement given those who set the fashions of the day?

Imagine the return of Raleigh to Great Britain and the social prestige which he must have had as the great explorer of the New World! Is it any wonder that men and, later, women, too,

have followed him in the smoking habit which he brought back with him? Consider the millions of acres devoted to tobacco to-day as a result of the smoking fashion.

The rise in favor of the potato is one of the most spectacular in the history of the introduction of new food plants. Sir Walter Raleigh is given credit for its introduction into Ireland. The friars of Spain took it to Italy. There are records of the governor of Mons having received it from the papal legate of Belgium. When we remember the rank of Raleigh and the standing of the Catholic Church, it is easy to understand how potato eating became fashionable in Ireland—came to be the great food crop of that island. It was, in my opinion, the fashion for it which started its cultivation.

Columbus, on his return to Spain, presented a sweet potato to Queen Isabella, and to-day it is an important root crop in Spain and one of the principal food plants of the Madeira Islanders. The Portuguese seamen took it to Japan in those days when they were the great and powerful foreigners in the eyes of the Japanese. To-day the sweet potato forms one of the principal crops grown on the upland fields of southwestern Japan, and is a most important food of the poorer classes.

The account given by the Japanese of the introduction of tea into Japan is a striking picture of the influence of a fashion upon a great plant industry. It was cultivated by the Chinese previous even to 2700 B.C., and had become fashionable there long before the Japanese introduced it into their ménu in 805 A.D. The Director of Agriculture of Japan, in his "Outlines of Agriculture," remarks that "at the beginning the Imperial court patronized and encouraged its cultivation, but later on the people at large began to appreciate it, so that it soon became an article of necessity for the people of all ranks and conditions in Japan. Therefore the cultivation of the tea plant has been extensively carried on in all quarters of the country, and the patronage given by the people in the upper class of society caused a striking improvement in the art of tea manufacture."

When we consider that the peach, the orange, the jujube, and at least one type of cherry and edible hawthorn originated in China, it is difficult to understand why fruits have not become more popular in Japan. The Director of Agriculture on this point is clear, for he says: "The Japanese have no custom of

eating fruits as dessert, so that the demand for fruits was comparatively limited; . . . but with the frequency of communications with European countries changes have been wrought in customs and usages of the people which have strikingly augmented the demand for fruits."

Compare this statement with the last report of our own Secretary of Agriculture: "It is a well-known fact that the consumption of fruits and vegetables has increased considerably in

TWO DASHEEN CORMS AND THEIR TUBERS.

These are the product of a single hill of dasheens. The tubers are easily broken off of the corms and can then be cooked and treated just as potatoes are. They contain more protein and starch per pound than the potato, and consequently require more butter or gravy. They have a delicious nutty flavor.

recent years, and that they constitute a larger and more important part of the permanent diet of the people."

I cannot avoid the feeling that these two officials, speaking of their own people as a whole, are a good deal like two mothers speaking of the peculiarities of their own families. "Well, my family won't eat that," is a familiar expression which one hears everywhere.

Did you ever watch an amœba, that primitive naked drop of protoplasm, send out one of its long feelers or pseudopodia toward a bit of copper or other substance, and, as soon as it comes within

the radius of the chemical activity, recoil and return to its rounded shape? Taste in its primitive form is there, and on up through all animals, before the birth of the great organ of intelligence, and even after, it is a guiding factor of existence. If the squash bug would only change its taste and be satisfied with the pigweed, or the cabbage butterfly larva with the pokeweed, or the codling moth with our wild cherry instead of the apple, or the dog become a vegetarian and leave the sheep alone, or the horse, like the goat, live on bark and twigs, or the cow refuse to eat garlic, or hawks and foxes confine their taste to owls and muskrats instead of molesting our chickens, or even if grasshoppers were not such omnivorous feeders and ate only grass instead of every living green thing, the world we live in would be different. But we cannot change these inherited tastes, though they even are being modified somewhat to meet the new conditions arising on the planet. There are conclusive proofs, for example, that cats and rabbits wandering through our gardens taste of the new plants which are put there. The cats of Boston learned in less than two years from the time of its introduction into America that a wild vine from central China was good to eat, and ate it to the ground. The wild rabbits of western Canada singled out, nibbled, and killed a new species of ash from Turkestan the first year it was grown in a nursery on the prairie.

The appearance of intelligent man in the world, however, creates a new situation, and it is a question whether instinctive taste has not already disappeared in him, although perhaps some of the vagaries of taste in foods which are hard to explain do come down as instinctive traces from our ancestors.

Taste is the avenue of our contact with the world of chemical things. It is, after all, one of our five senses. Is it not worthy of all the study which can be given to it, and should not the education of the human palate become a matter of great importance and every effort be made to teach the value of a wide liking for everything that is good to eat? Let us not be misled by those who scoff at the problem. Scoffing is a trait unworthy of intelligent man. Think of the conservatories of music where the sense of hearing of thousands of our youth is trained, and the academies of art where the sense of sight is cultivated, and then compare these with the schools of Domestic Economy and see what a gulf there is between them. How far we must yet go to

put the cultivation of the American palate where it really belongs!

The question, it seems to me, may with perfect propriety be asked in regard to our children, Are they not already acquiring incurable habits in foods? How many housewives stop to realize how the taste for sugar has grown in this country, or that, whereas France must limit each citizen to twelve pounds per year, we are said to be eating in the neighborhood of ninety. There was a time in the Middle Ages—and that is, after all, not many generations ago—when the only sweet things man had were

A FIELD OF DASHEENS IN FLORIDA (*Colocasia esculenta*).

The dasheen plant looks like the "elephant ear" of our gardens. It grows on soil which is too moist for the potato, and its tubers mature in November in the South, when potatoes are being shipped in from the North. When this vegetable becomes widely known, hundreds of thousands of acres of land not now utilized profitably will probably be planted to it.

honey, raisins, and such things as sweet fruits. Sugars were unknown and probably not liked by hosts of our ancestors—there are some to-day who do not care for sweets; but the sugar habit, like the tobacco habit or the chewing-gum habit or the alcohol habit, is going to bring about acute suffering in those who must give it up or curtail it, just as the bread habit and the meat habit are hard to change.

We have a curious spectacle in our common schools—thousands of little children poring over books on the volcanoes of the world which they will never see, the North Pole, which they can

never expect to visit, and, when the noon hour comes, satisfying their hunger from their dinner pails with no word from the teacher regarding perhaps the most acute sense they have—the sense of taste.

I left school and college with about as untrained a palate as I had when I started in, and it took the knocks of travel to demonstrate to me the desirability, the necessity at times, of learning to like everything which is fit to eat.

The researches of modern chemistry have revealed startling things with regard to the requirements of our bodies—things which cannot fail to make one feel that discoveries of gigantic importance may at any time be made. To learn that rats or pigs will starve to death on an exclusive diet of Indian corn; that the rice we have all been eating will, if taken alone, produce the starvation disease known as beri beri; that a few cubic centimetres of the white of egg, if injected into the blood, so sensitizes the protoplasm of our bodies that a second dose will kill us almost as quickly as a dose of snake venom, are facts which make us wonder what discoveries we are approaching.

The consideration of food as fuel was a great step in advance in the food question, but the discovery of McCollum, that certain substances contained in butter fat and the green leaves of plants are just as essential for a complete food as the proteins, fats, carbohydrates, and mineral constituents contained in grains, has opened a new door of possibility. The machinery for determining the comparative protoplasma building and conserving value of foods is rapidly being created, and it is curious to reflect that the despised rat is being made one of the chief tools by means of which the food chemist is working them out. The human calorimeter, which amused the public at first, has come into prominence as one of the great tools of this generation. We are in a position such as we have never occupied before to test the value of the food plants of the world.

All these converging changes, it seems to me, indicate the present as a remarkable opportunity in which to consider whether the stone wall of taste is really a stone wall, or whether it is something which the reason of man can tear down—whether, in other words, the time has not arrived when we should cease insisting that our likes and dislikes in foods are nobody's business anyhow, and begin to realize in how far this caprice of fashion will hinder the development of the agriculture of the future.

"De gustibus non disputandum" is an expression which was originated by the scholastics of the Middle Ages and has, curiously enough, blocked for centuries the discussion of one of the most important subjects connected with the development of the human race.

The fact that plants can be found which are suited to different soils and climates, easier than the soils and climates can be changed, has been conclusively demonstrated. The date palm is perfectly

FACTORY FOR PRODUCTION OF SOY BEAN PRODUCTS.

The Japanese and Chinese do not eat soy beans as we do the navy beans. They make curds and cheeses and the remarkable soy sauce out of them. This soy sauce takes the place of meat gravy in the diet of hundreds of millions of people, and is worthy of the serious consideration of Americans. It is consumed in immense quantities by all these people. The *per capita* consumption reaches ten quarts a year in Japan. It is about as strong in flavoring power as beef extract. The taste for soy sauce in America is growing, and is being stimulated by the Chinese restaurants of the country.

at home in the Imperial Valley where the apple is a dead failure. The dasheen is a success on soils too wet for the potato. The kafir sorghums live and bear heavily on lands too dry for corn. Wheat cannot be grown everywhere, potatoes are a success only in certain regions on certain soils, and there are enough types of soil and climate to make places for more crops than most people know exist in the whole world.

The spread of plant diseases and the cost of their control is another factor forcing man to change his crops. Already in

certain plant industries they are taking all the profits out of the cultivation of those plants. As the plantations of one crop grow in size and are owned by larger numbers of individuals, these costs of control often increase, and our farmers should be able to shift to other crops less liable to disease.

The pear blight has wiped out great orchard areas in this country, and other crops have taken their place; the watermelon

FRUITING BRANCH OF THE CHINESE JUJUBE (*Ziziphus sativa*).

The Chinese large-fruited jujube constitutes a new fruit tree for America. It is adapted to the hottest regions of the Southwest, where it fruits abundantly. The fruits shrivel on the tree and can be gathered and kept in a dry state, to be processed with sugar later or used like raisins in puddings. The processed jujube is not inferior to the Persian date in flavor. This is the Mu shing hong variety (S. P. I. No. 22684).

disease has made watermelon growing unprofitable in certain sections; the glume rust of wheat threatens serious injury to the wheat area of the Northwest; the nematodes of Southern soils make fig growing in many places there impossible; the new peach twig borer may be the last straw that will discourage peach growing wherever it spreads; the American chestnut has already practically gone, and we will be dependent probably upon some immune hybrid between the Japanese chestnut and the chinquapin for our Thanksgiving chestnuts.

Armsby has emphasized the limitations of the hog and the steer as producers of necessary food material when fed on human food grains. Lusk points out the fact that indulgence in meat is due primarily to desire for strong flavor, and these facts may make meat too expensive for some of us and drive us to the use of soy sauce, the great flavoring extract of the Orientals. These peoples have not acquired the expensive taste for beef; in the place of beef gravies they consume over ten quarts per adult per year of a sauce made from soy beans and wheat—a teaspoonful or so at a meal. That changes in our ménus are coming there can be no doubt. The above causes are at work, and some of the changes that we may have to adjust ourselves to in the next generation may be surprising.

Conservatism in taste has no doubt been a great stabilizer, but has it not increased the chances for speculation and made "corners" possible? It has enabled the farmer to know with some degree of certainty when he plants his orchard that there will be a demand for the product of his orchard ten years hence. Doubt as to the existence of this demand will prevent him from planting the orchard. It has simplified, no doubt, some of the marketing problems which depend upon advertising. The change of fashions in foods adds one more element to the gamble of agriculture. A broad universal diet, however, should give room for the development of all the good plant and animal foods of the world. Our American children of the next generation should be more untrammelled than we have been in their diet, and able at any time to shift from one food product to another as the price or shortage dictates. They should have a mobility of action which will enable them to go anywhere and eat anything fit to eat, and test out and eliminate or keep, as the case may be, any new foods which the investigations and experiments of plant introduction and plant breeding and the growing genius of food chemistry will surely bring into existence.

But throughout all this discussion I cannot help wishing that the great man Franklin, the greatest in some ways that America has produced, could look up from his bowl of porridge, which he says in his autobiography formed for years his daily breakfast, and tell us how this great country can be utilized agriculturally, if everybody should insist on a breakfast of oatmeal porridge and milk and nothing more.

PROPULSION OF SHIPS.*

BY

ESKIL BERG,

General Electric Company, Schenectady, N. Y.

IT is doubtful if any branch of engineering has advanced as slowly and cautiously as that branch of marine engineering which has to do with the propelling of machinery. Reliability seems to have been the only thing in view, and economy seems, until very lately, to have received very little consideration.

As an illustration of this point, I would mention that some of the Hudson River boats still have side wheels and use boilers with about 30 pounds steam pressure, producing a brake horsepower with about 30 or 40 pounds of steam.

Steam engines were built as early as 1765, but it was not until 1807 that one was used to propel a boat. Electricity was used for power transmission as long ago as 1876, but its application as a medium for transmitting power to the propeller of a ship did not take place until 1908. This all goes to show that progress in marine propulsion is very slow, the tendency being to follow the old and beaten paths.

Until within the last few years, reciprocating engines were used exclusively for the propulsion of boats, but with the advent of the steam turbine and its almost universal use on shore, where, due to its high steam economy, small size, and light weight, it has practically superseded the reciprocating engine, the practicability of its use for the propulsion of ships began to be considered. It is largely due to the untiring efforts of Sir Charles Parsons that turbines are now rapidly replacing reciprocating engines for the propulsion of ships. It may not be out of the scope of this paper to give some of the reasons why the turbine is preferable to the reciprocating engine as a prime mover.

First: Because it gives simple rotation and admits the possibility of a large range of expansion. At present the best steam engines of the triple- and quadruple-expansion type cannot, on

* Presented at a joint meeting of the Electrical Section of the Institute and the Philadelphia Section, American Institute of Electrical Engineers, held Thursday, October 11, 1917.

account of the size of the low-pressure cylinder, be made with an expansion ratio of more than 16 to 1 or 20 to 1. In the turbines, however, there are practically unlimited possibilities of expansion, depending almost entirely upon the temperature of the condensing water. A vacuum of 29 inches is not at all an unusual occurrence, and 29.5 inches is being recorded in some of the larger central stations during the winter months. What this means may be better understood when we consider the available energy of a pound of steam when it is expanded from boiler pressure to various degrees of vacuum.

200 pounds pressure to 24 inches vacuum.... 220,000 foot-pounds
200 pounds pressure to 26 inches vacuum.... 238,000 foot-pounds
200 pounds pressure to 28 inches vacuum.... 265,000 foot-pounds
200 pounds pressure to 29 inches vacuum.... 289,000 foot-pounds

In other words, a turbine can realize about 25 per cent. more of the energy of the steam than the reciprocating engine, which means a saving of 25 per cent. in fuel, size of boilers, etc.

The small size of the turbines is, of course, another very important item. Incidentally there are a great many minor advantages, such as saving of oil, attendance, ash handling facilities, etc.

When the turbine is considered for ship propulsion there are a few facts that must be borne in mind, namely:

High-speed turbines are lighter, cheaper, simpler, and more economical than the slow-speed turbine. Propellers, on the other hand, are, within well-known limits, confined to slow speeds for high efficeincy. Turbines, therefore, when used for direct connection to the propeller shaft, must necessarily be designed to operate at a speed which is too low for the economical use of steam, and even then cannot be conveniently designed for a speed low enough to secure efficient propeller action. Parsons realized this and advocated the use of direct-connected turbines only for high-speed ocean liners requiring a large amount of power, and the *Mauretania* is probably one of the best examples of ships using this method of propulsion. The horsepower of the *Mauretania* is 68,000, the speed about 26 knots, and about 43.5 tons of coal per hour is required. The water rate obtained is about 11.5 or 12 pounds and the coal consumption about 1.5 pounds per shaft horsepower-hour.

A few years later, when the White Star Line decided to build the *Olympic* and the *Titanic,* which were slow-speed ships requiring about 45,000 horsepower, Mr. Parsons advocated a combination of two reciprocating engines exhausting into a low-pressure turbine, which gave him an economy about comparable with the *Mauretania.*

As you doubtless all know, the steam engine is a very efficient prime mover when operating in the higher temperature ranges; that is, an engine may have as high as 80 per cent. thermodynamic efficiency when operating from boiler pressure to atmosphere, whereas if it was operated down to a 28-inch vacuum the efficiency would not be greater than 40 or 50 per cent. On the other hand, the turbine works efficiently in the low-pressure end of the cycle, so that by using a reciprocating engine in the upper ranges in combination with a turbine to utilize the energy in the low-pressure ranges an overall efficiency is obtained which may be above that obtainable with either the reciprocating engine or the turbine when working alone. In the *Olympic,* all reversing and manœuvring is done with the reciprocating engines, making it possible to build a simple and efficient low-pressure turbine.

It is therefore necessary, in order to obtain the advantages of the high-speed turbine and at the same time to be able to use a low-speed efficient propeller, to have some form of reduction gear between the propeller and the prime mover. This condition is what led up to the application of electricity to the propulsion of ships, to the mechanical reduction gear, and also to speed reduction by means of hydraulic transmission. Electric propulsion is best suited to very large, high-powered vessels, especially in cases where good economy is desired at two or more speeds, as in the case of warships. The reasons for this are as follows:

Electric transmission affords a very simple and practical means of speed reduction in almost any ratio which may be desired.

It affords a very simple means of reversal by a change of electrical connections without mechanical devices, complication of piping, valves, etc. Any desired reversing torque can be obtained without affecting the efficiency of the equipment in the forward direction.

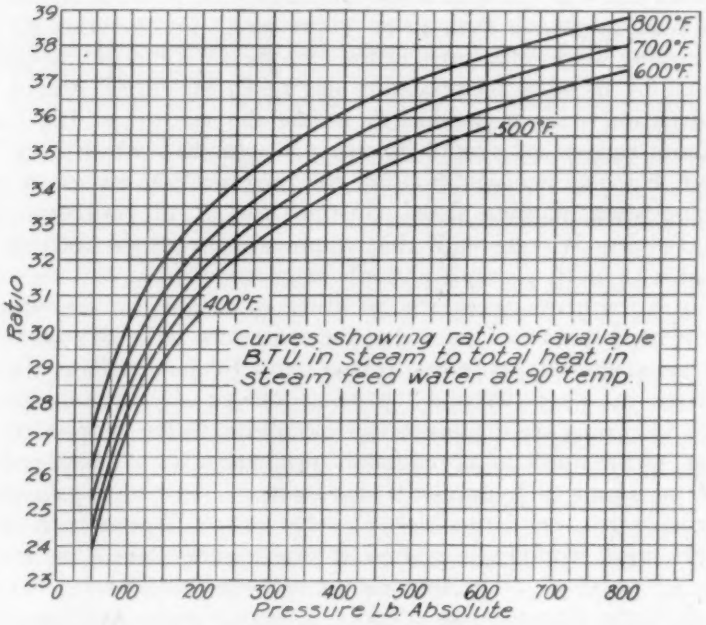
In the case of battleships, the feature that is particularly important is that electric transmission affords means by which the

ratio of speed reduction is changeable by simple electrical connections, thus making possible the economical use of the same apparatus, both under high-speed and cruising conditions.

Electric transmission makes it possible to use a plurality of cruising and generating units, so that damage to one or more parts will not disable the vessel.

With electric transmission, high steam pressure and superheat can safely be used, and the gain in fuel economy by its use is best shown by these curves. A steam temperature of 700° is now

FIG. 1.



successfully used in Europe, which with 500 pounds steam pressure would give a superheat of 233°. Heat available for work would then be about 36.3 per cent., whereas under ordinary steam conditions, say 200 pounds pressure and 50° superheat, we have only 30.75 per cent. available, a net gain of 18 per cent. in fuel, which would more than compensate for any additional weight or cost of the electrical equipment.

Turbo-generators are now built with an efficiency of over 80 per cent., which with motors of 95 per cent. efficiency and a

boiler efficiency of 80 per cent. would produce a shaft horsepower-hour with 0.825 pound of coal (containing 14,000 British thermal units per pound) or 0.61 pound of oil (19,000 British thermal units per pound), the latter figure comparing favorably with Diesel engines when lubricating oil is taken into consideration.

The first electrically propelled boats in this country (outside of electric launches) were two fireboats in the city of Chicago, the *Joseph Medill* and the *Graeme Stewart,* which were equipped with electric propelling machinery in 1908. Their equipment consists of two Curtis turbo-generating units of 1000 horsepower capacity each. Each turbine is connected to a 250-kilowatt, direct-current generator and a 1000-horsepower centrifugal pump. There are two propellers, each driven by a 250-horsepower, direct-current, 220-volt motor. The equipment is arranged for pilot-house control. The wonderful manœuvring qualities, simplicity of control, and fine economy of these boats, together with the fact that up to the present time no money has been spent for repairs to the electric propelling machinery, make the vessels the most efficient fireboats in the country and probably in the world. In the case of these fireboats, direct-current apparatus, with its complication of brushes and commutators, was used, but for larger installations alternating current is used, which greatly simplifies the apparatus.

The second example of electric propulsion is the large United States collier *Jupiter.* Due to the wonderfully fine performance of this collier, which has now been in service for about four years, the Navy Department decided to install electric propelling machinery in the battleship *New Mexico,* which is now nearly completed at the New York Navy Yard, and the apparatus for which has recently passed all government tests at the Schenectady Works of the General Electric Company. The Navy Department has also decided to install electric propelling machinery in six other new battleships requiring about 33,000 horsepower each, and in five large battle cruisers requiring about 180,000 horsepower each.

Mr. W. L. R. Emmet, to whom all credit is due for the introduction of electric drive in vessels in this country, read a paper before this Institute, about four years ago, describing quite fully the *Jupiter* equipment as being built, and predicted results in regard to economy which have more than been borne out in

actual service. A short description of the *Jupiter* will be given.

The *Jupiter* is a sister ship of the *Cyclops* and the *Neptune*. They each have 20,000 tons displacement and a carrying capacity of about 12,000 tons of cargo. The principal dimensions are: Length, 548 feet; breadth, 65 feet; depth, 39¼ feet; draught, 27 feet 6 inches. The *Cyclops* is equipped with reciprocating engines and the *Neptune* with Parsons geared turbines (built by the Westinghouse Company).

In giving the General Electric Company the contract for the *Jupiter* equipment, a water rate of 13 pounds per shaft horsepower at 14 knots and 15 pounds per shaft horsepower at 10 knots was guaranteed. It was also provided that in case of failure of the electrical equipment it should be removed without expense to the government, so that reciprocating engines which were originally contemplated for this vessel could be installed in its place. This feature limited the design somewhat, for, while it was believed by its designers that electric propulsion would show a great advantage over any other system, even greater improvement could have been accomplished if the vessel had been designed with a view to obtaining all the advantages incident to electric drive.

During her official trials the *Jupiter* maintained an average speed of 15 knots for 48 hours, with 7152 horsepower delivered to the propeller shafts and a propeller speed of 116.72 revolutions per minute. The water rate as actually measured was 11.68 pounds per shaft horsepower-hour. Due to the fact that the steam pipe between the boiler and turbine was too small, the steam pressure at the turbine was only 168 pounds instead of 190 pounds, for which the machine was designed. Since the official trials took place a larger steam pipe has been installed and the water rate reduced to 11 pounds.

During her 10-knot run the water rate was 12.31 pounds. It will be seen from this that the guaranteed water rates of 13 and 15 pounds were beaten by about 20 per cent. The *Jupiter* is to-day, according to the government records, making a speed of 12 knots with a coal consumption of only 55 tons a day, which is a record about 35 per cent. better than any boat of her size afloat to-day. The *Cyclops* on her trials developed 14.6 knots with about 6000 horsepower and a steam consumption of about 14 pounds, or about 25 per cent. greater than the *Jupiter*.

The *Neptune*, equipped with Parsons geared turbines, has just recently had her trials and the published results give us the following comparison with the *Jupiter* and *Cyclops:*

	U. S. Naval Colliers		
	Cyclops	*Neptune*	*Jupiter*
Weight of propelling machinery only, tons.....	280	150	156
Steam consumption at maximum speed, pounds per shaft horsepower-hour	14.0	13.4	11.1

The equipment of the Jupiter consists of one turbo-generating unit with an induction motor coupled to each of the two propeller shafts. The generator is of the 3-phase type designed for a normal output of 5000 kilowatt at 2300 volts. At a speed of 14 knots the turbine runs at about 2000 revolutions per minute and the motors at 110 revolutions per minute. The generator has two poles and the motors 36 poles, making a speed reduction of 18 to 1.

The speed of the ship is controlled by a governor which was specially designed for a very wide range of speed adjustment. It operates from the maximum speed down to a speed of four or five knots per hour. The speed can also be controlled independently from the main throttle valve, which is also designed so that in case of excess speed it is closed automatically by the emergency governor, which operates independently from the main governor and is set to close at a speed slightly higher than the maximum speed of the boat.

The motors are of the 3-phase induction type and have 36 poles. The windings are made waterproof. The rotor windings of the motors are connected to collector rings, which under normal conditions are short-circuited by a slider on the shaft. These collector rings are connected by means of brushes to water-cooled resistances, which are provided for the purpose of obtaining a high torque in starting or reversing. In this particular case they are designed to give more than full-load torque. When the motors are running with this resistance in the circuit the current flowing to the motors is always limited so that all the manœuvring can be done by simply opening and closing the ahead and reversing switches.

When running with the resistance in, the *Jupiter* will reach a speed of about 10 knots. These resistances afford a very quick and powerful reversal, but the ship can be operated without them,

and is, as a matter of fact, a great deal of the time. In this case, reversing is accomplished by slowing down the generating unit, which also slows down the propellers, the reverse connections are made, and the turbine again brought up to speed, which will bring the motors up to speed in the reverse direction.

The switchboard equipment is very simple. It consists of one ahead and one reversing switch for each motor, a field switch for the generator, ammeter, voltmeter, wattmeters, and frequency meters graduated in revolutions per minute. The switchboard has also integrating wattmeters which record on a dial the total amount of power going to each motor and makes a very interesting record for each trip of the boat.

The excitation of the generator is obtained from the lighting circuit of the ship, which consists of three small turbine-driven, direct-current generating sets. One of these sets is more than sufficient to furnish the necessary excitation.

The third instance of electric propulsion is the new U. S. battleship *New Mexico,* which is now under construction at the New York Navy Yard. This installation provides conditions where the advantages of electric propulsion can be realized. The *New Mexico* is the largest and most powerful battleship which has been laid down by our navy up to the present time. She will have a displacement of 32,000 tons and a designed speed of 21 knots, requiring about 28,000 horsepower. The propelling machinery is, however, designed to deliver a maximum of 37,000 horsepower, and it is believed that this will give her a speed of 22 knots.

The equipment will consist of two turbo-generating units, four propelling motors (one for each shaft), switching apparatus, cables, instruments, etc. The contract also calls for two 300-kilowatt non-condensing, direct-current turbo-generators, which will furnish excitation and power to drive the auxiliary machinery. As the General Electric Company was required to guarantee the steam consumption of the propelling machinery, including the auxiliaries, the greatest care was taken in their selection, and they are all to be electrically driven. The exhaust steam from the direct-current generating sets which operate non-condensing will be used for heating the feed water, and any that may not be required for this purpose will be exhausted into the main turbine. The generators for the *New Mexico* are bi-polar alternators, and

the motors are arranged to be connected for either 24 or 36 poles. For economic cruising at a speed of 15 knots or less, only one generating unit will be required with the motors on the 36-pole connection. For higher speeds the 24-pole motor connection will be used with both generators. One generator, however, will be capable of driving the boat up to a speed of about 19 knots.

Speed variations with either motor connection will be obtained by varying the generator speed, and a governor will be installed similar to that used with the *Jupiter* equipment.

The steam consumption guarantees as made to the government cover the total amount of steam used both by the main generating units and the auxiliaries, and are as follows:

Steam Pressure 250 Pounds Gauge at Throttle.

10 knots	14.6	pounds per shaft horsepower-hour
15 knots	11.4	pounds per shaft horsepower-hour
19 knots	11.1	pounds per shaft horsepower-hour
Max. speed	11.9	pounds per shaft horsepower-hour

Very heavy penalties are attached to these guarantees in case they are not met, namely, $25,000 per pound for the two lower speeds and $20,000 per pound for the two higher speeds.

At full speed the *New Mexico's* propellers will operate at 175 revolutions per minute, the lowest speed permissible within the space allowed. The propeller speed for the sister ship of the *New Mexico* with Parsons type turbines is 240 revolutions per minute, which, according to Captain Dyson, would indicate a propeller efficiency 9 per cent. worse than is expected on the *New Mexico,* and this difference would more than compensate for the electrical losses in the motors and generators.

In order to be able to correctly judge the relative economy of different methods of propulsion, it may be interesting to compare the water rate per effective horsepower, taking for examples of such different methods the battleships *Florida* and *Utah,* which are equipped with Parsons turbines; the *Delaware,* which has reciprocating engines, and the *New Mexico,* with electric drive.

	Propeller Speed	Water rate per effective horsepower per hour. 12 knots	19 knots	21 knots
Florida	328	31.8	24.0	23.0
Utah	323	28.7	20.3	21.0
Delaware	122	22.0	18.7	21.0
New Mexico	175	17.3	15.0	16.4

The guaranteed weight of the propelling machinery for the *New Mexico* without the auxiliaries is 530 tons, with a penalty of $500 per ton for any excess over this amount. The estimated weight of the Parsons turbine equipment for this vessel was 653 tons.

The contract price for the *New Mexico* machinery was $431,000, and the Navy Yard estimates show that a saving of $200,000 will be effected by using this equipment instead of the Parsons equipment as originally contemplated.

ELECTRIC PROPULSION FOR LARGE BATTLE CRUISERS.

These vessels are designed to have a speed of 35 knots, at which speed they will require about 180,000 horsepower. There are four propellers operating at 250 revolutions per minute at maximum speed.

The installation proposed for these ships consists of four high-speed turbo-generators, each having a capacity of about 35,000 kilowatts. On each propeller shaft there will be two independent induction motors, each having a capacity of 22,500 horsepower. The switchboard will be provided with an arrangement by which any combination of generating units and motors can be used, and starting, stopping, and reversing can be instantly done by movement of a lever. All changes of connections are made on dead circuits, so that there can never be any big rushes of current to strain the apparatus. Safety devices are also provided so that any unbalancing of current will open the circuit of that particular unit in which it occurs.

The total weight of the complete equipment for one of these vessels is about 1800 tons, of which the turbines alone weight about 350 tons.

That electric propulsion can also be profitably applied to a small boat is proved by Mr. Ljungstrom, in Sweden, in the case of the small coastwise steamer *Mjolner,* which is only 225 feet long, 56 feet beam, and 15 feet draught, requiring 900 horsepower. Stockholm's Rederiaktiebolajet Svea decided to build two sister ships, the *Mimer* and the *Mjolner.* The *Mimer* was equipped with triple-expansion engines, and Mr. Ljungstrom guaranteed a saving of 30 per cent. in fuel with his method of electric propulsion in the *Mjolner* over the *Mimer* equipped with engines. The boats have now been built and tested, and the electrically

propelled boat showed a saving of 42.3 per cent. in fuel consumption. This is indeed a remarkable record, but may be partly explained by the increased efficiency of the boiler plant. For his electric drive Ljungstrom uses 218 pounds steam pressure and 235° superheat, and this alone would effect a saving in coal over the *Mimer* of about 15 per cent.

In this boat Ljungstrom uses two 400-kilowatt turbines running at 7200 revolutions per minute, generating 3-phase, 120-cycle current at 500 volts. This current is used to drive two induction motors which are geared to the main propeller shaft. The motors run at 900 revolutions per minute and the propeller shaft at 90 revolutions per minute. All of the auxiliaries are electrically driven, which affords another appreciable saving.

Mr. Ljungstrom has done some wonderfully fine engineering in connection with this equipment and has combined electric propulsion with mechanical gearing, which is a great step forward.

The greatest competitor of electric drive at the present time is the high-speed helical gearing which is now coming into such universal use. This method of drive has, however, certain limitations as compared with electric drive, some of which I will endeavor to mention. The manœuvring qualities cannot be made equally as good as with electric drive. Noise is, of course, practically eliminated with electric drive, whereas with gearing there must be some noise. There are also certain mechanical limitations to the use of gears which do not exist with electric drive. Briefly stated they are as follows:

The stresses on the tooth surfaces increase with the diminution in the number of teeth in the pinion, making it difficult to use very small pinions in order to secure large ratios of speed reduction. The length of the pinion and the output for a given diameter is limited, due to the torsional elasticity of the metal, which prevents equal distribution of load over the whole surface. As the gears become large and long, springing of the hull of the ship in a heavy seaway tends to throw very heavy strains on the teeth.

For installations where a large amount of power is required, multiplications of pinions becomes necessary, which means dividing up the turbine element into smaller units. This, of course, tends to decrease the efficiency, increase the weight, and produce a much more complicated outfit. In cases where large powers are

required with slow-speed propellers, the gears become very large and expansion strains due to heat may introduce great errors in the surface engagement of the gears which would throw prohibitive strains on the teeth.

With gear drive, reversing turbines are always necessary, and they introduce considerable loss, as they are always running in the reverse direction when the ship is going ahead. The losses due to this turbine friction amount to about 1½ to 2 per cent.

At the present time, for vessels requiring up to about 12,000

FIG. 2.

1750-horsepower turbine and 3200/137 R. P. M. reduction gear for U. S. S. *Nevada*.

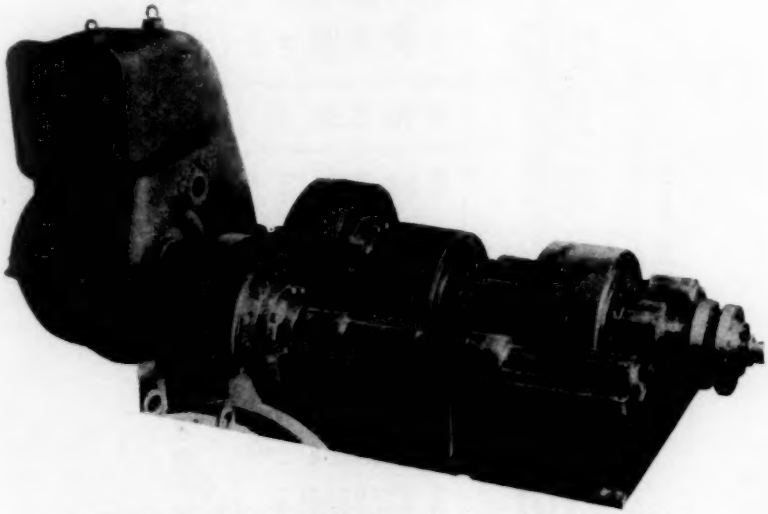
horsepower, or 6000 horsepower on each propeller shaft, mechanical gearing is lighter, cheaper, and more efficient than electric drive. For destroyers or light scout cruisers, where saving of weight is of the utmost importance, the high-speed geared turbine has no competitor.

About five years ago the General Electric Company began experimenting with flexible gears of the Alquist type, and results obtained showed that with this type of gear heavier loads could be carried than with solid gears, also that the noise was very materially reduced. The Alquist flexible gears are built up from

disks suitably formed so as to facilitate axial deflection. On account of helical angle there is a component of the driving pressure acting at right angles to the disks, and it is evident that the resultant axial deflection causes also a relative displacement of the tooth line in the direction of the drive.

On account of this flexibility, an equal pressure is assured for all of the disks and an equal distribution of pressure along the driving line. The freedom from heavy overloads, which in solid gears is caused by errors in cutting at some part of the tooth surface and more especially at the ends of the teeth by the twisting

FIG. 3.



Curtis turbine and one-plane flexible type reduction gear for ship propulsion.

of the pinion under load, makes it possible to use a finer pitch than in solid gears, and this, of course, increases the output for the same length of pinion. To understand this, it must be remembered that the shape or curvature of the teeth does not depend upon the diametrical pitch, but only on the gear diameters. The finer the pitch, the more driving points per unit length of face and the greater load which can be carried.

Gearing of this type has been applied to about 150 high-speed turbines for connection to electric generators, and the unqualified success of these sets after two years of hard service led the

S. S. "LA BREA"

Voyage	Date	Total distance in knots	Average speed in knots per hour	Total barrels delivered	Name of port	Total fuel used steaming on voyage in barrels	Total barrels per knots steaming	Total barrels used in port	Total barrels per knot steaming and in port	Time in port hours	Barrels discharged per hour	Cost at 80 cents per barrel per knot steaming and in port (fuel)	Shaft horsepower-hours	Pounds of oil per shaft horsepower
1	March 9 to 15, 1916	650	9.5	62578	Oleum	574	.883	142	1.10	36½	1714	$ .88	116000	1.67
2	March 15 to 26	2037	11.33	73600	Seattle	1459	.716	152	.79	37½	1962	.632	505000	.941
3	March 28 to April 6	2108	11.01	64676 8642	Vancouver Seattle	1584	.751	155	.824	26 13½	2487 640	.659	530000	1.01
4	April 8 to May 16	92545	10.97	52109 19045	Taltal Antofagasta	6896	.745	117	.757	33¾ 15½	1544 1228	.605	2330000	1.00
5	May 17 to 23	450	11.20	77292	Oleum	321	.713	134	1.01	39	1980	.808	118000	.911
6	May 24 to July 1	91965	10.65	71824	Antofagasta	6900	.75	109	.762	25	2660	.609	2200000	1.06
7	July 1 to Aug. 9	9184	10.39	71791	Port San Luis to Antofagasta, Chili, and return	6875	.748	107	.76	42.3	1697	.609	2230000	1.04
	Average speed..... 10.9													

Total pounds of oil steaming, 8,270,000. Total shaft horsepower-hours, 8,029,000. Pounds of oil per shaft horsepower-hour, 1.03.

S. S. "LOS ANGELES"

Voyage	Date	Total distance in knots	Average speed in knots per hour	Total barrels delivered	Name of port	Total fuel used steaming on voyage in barrels	Total barrels per knots steaming	Total barrels used in port	Total barrels per knot steaming and in port	Time in port hours	Barrels discharged per hour	Cost at 80 cents per barrel per knot steaming and in port (fuel)	Shaft horsepower-hours	Pounds of oil per shaft horsepower
1	April 9 to 15	423	9.4	67674	Oleum	556	1.31	164	1.70	64½	1099	$1.36	74600	2.48
2	April 16 to 25	1845	10.13	74739	Vancouver	1656	.897	218	1.01	33¾	2214	.808	394000	1.41
3	April 27 to May 25	6549	10.22	73734	Panama	5579	.851	169	.877	46¾	1577	.701	1420000	1.315
4	May 26 to 29	220	9.1	72372	Oleum	221	1.00	123	1.56	41	1770	1.24	39000	1.88
5	May 30 to June 27	6348	10.6	72538	Balboa	5462	.86	159	.885	35	2072	.708	1460000	1.255
6	June 29 to Aug. 7, 1916	9151	10.24	71007	Port San Luis to Antofagasta, Chili, and return	8293	.906	186	.926	56.3	1261	.74	2130000	1.31
	Average speed..... 10.27													

Total pounds of oil steaming, 7,310,000. Total shaft horsepower-hours, 5,538,000. Pounds of oil per shaft horsepower-hour, 1.320.

General Electric Company to enter the marine field. Contracts have now been closed for about 250 marine propulsion sets, aggregating about 700,000 horsepower; about 40 of them are now in operation, and a few of them have gone about 100,000 knots with no replacement of either pinion or gears. Among the more important installations I may mention the cruising turbines for the battleship *Nevada*, which have now been in operation for almost two years. There are also about 25 2400-horsepower outfits in operation, as well as the two Luckenback boats, each of 4000 horsepower, which on their trial trip developed 5200 horsepower. Among the important sets now being built may be mentioned the equipmnt for U. S. Destroyer No. 69, having 21,000 horsepower and the U. S. S. *Salem*, having 20,000 horsepower.

The tables (pp. 330 and 331) show a comparison of the *La Brea* and *Los Angeles*, the former equipped with a geared Curtis turbine and the latter with a triple-expansion engine. It will be noted that the *La Brea* consumed only 1 pound of fuel oil per shaft horsepower, as compared with 1.31 pounds for the sister ship.

There is still another method of speed reduction; namely, the hydraulic gear as proposed by Doctor Föttinger in Europe, which consists of a centrifugal pump driving a water motor. With this arrangement he has obtained a combined efficiency of 90 per cent. with a speed reduction of 4 to 1. The efficiency falls off very rapidly, however, with higher ratios of speed reduction, and reaches about 80 per cent. with a speed ratio of 10 to 1. The mine-laying vessel *Koenigin Louise* was equipped in this way, this vessel having been sunk during the present war. Rapid wear and small clearances are the principal difficulties with this method of propulsion.

This paper has described to you some of the latest developments in marine propulsion and shows that the United States has again taken the lead in marine engineering. With the activities now going on in shipbuildng in this country, we can look forward in the near future to even greater results.

OCCLUDED GASES IN FERROUS ALLOYS.*

BY

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The rubber stoppers, when heated for several days at a temperature of 100° C., evolved only a few cubic centimetres of air, and it was therefore concluded that either the porcelain tube or the thermocouple evolved gas when heated in a vacuum. It had previously been noted by Fox, in his thesis for the degree of Master of Science at Massachusetts Institute of Technology, in 1886, that small amounts of gas either were dissolved in, or adhered to, porcelain. Before each determination the tube was allowed to stand under a vacuum for at least 48 hours in order that any free gas might be removed from the apparatus.

In preparing the material for Baker's first determinations, equal quantities of converted bar were melted in two crucibles in the same coke-fired oven. Aluminum was added to one sample. Both samples were then cast in moulds 6 cm. square, with the result that the ingot to which the aluminum had been added was sound, whereas the other ingot contained a number of blowholes. The chemical analysis of the ingots follows:

Element	Sound ingot, per cent.	Unsound ingot, per cent.
Combined carbon	0.810	0.900
Silicon	.080	.088
Manganese	.050	.096
Aluminum	.033	....
Sulphur	.028	.023
Phosphorus	.019	.019

Test bars were cut from each of these ingots and determinations made by heating the test bars ten days for eleven hours each day. In the case of the unsound steel, many of the blowholes were cut open before heating, in order that the gas might escape, since it was Baker's object to determine the gas evolved

* Continued from page 198, vol. 185, February, 1918.

from the solid portion of the steel alone. It was found that the sound steel evolved a total of 91.86 c.c. of gas, or about 12.2 c.c. of gas per cubic centimetre of metal. Hydrogen was evolved first at 300° C. (dv/dt), reached a maximum at 600° C., decreased until 900° C. was reached, and then increased with the temperature. More than 90 per cent. of the gas evolved up to 500° C. was composed of hydrogen. Carbon monoxide was first evolved at 600° C. (dv/dt), increased to a maximum at 690° C., decreased to a minimum at 800° C., and finally increased with the higher temperature, as did hydrogen. Above 760° C. equal volumes of hydrogen and of carbon monoxide were evolved. In the case of the unsound steel similar changes were observed. The total volume of gas obtained from the defective steel, however, was much smaller than the volume obtained from the sound steel, only 42.09 c.c. of gas, or 5.2 c.c. of gas per cubic centimetre of metal, being evolved. Baker found that a maximum of gas evolution occurred at the points Ar_1, Ar_2, Ar_3 with both samples of steel, this maximum being much greater in the case of the sound steel. He concluded that the increase in (dv/dt) must have been due to carbon monoxide, since hydrogen was past its maximum. He was of the opinion that the increase could have been due to one of two causes: either the inferior solubility of carbon monoxide in gamma iron; or the decomposition of a chemical compound of carbon monoxide and iron.

Baker next attempted to determine whether or not any action occurred between the steel samples and the porcelain of the tubes used. A blank determination was first conducted on one of the tubes, with the following evolution of gas upon heating:

Volume in c.c.		Per cent. CO_2	Per cent. H	Per cent. CO	Per cent. CH_4	Per cent. N
1st period	4.21	22.80	55.58	15.67	3.31	2.61
2d period	3.51	9.37	65.62	18.81	1.42	5.11
3d period	3.16	12.97	73.41	5.69	.63	7.27
Total	10.88					

Each period of heating lasted for three hours.

Forty grammes of the sound steel previously used was then placed in a platinum boat and heated at 800° C. during 8 days for 11 hours a day. Fifty-three and sixty-seven hundredths c.c. of gas, or 10.5 c.c. of gas per cubic centimetre of metal was

evolved (Table VI). This same steel heated in contact with the porcelain tube at a temperature of 802° C. evolved 9.03 c.c. of gas per cubic centimetre of metal (Table VI). Since these results correspond so closely, it was concluded that the fact that the steel was in contact with the tube in some of the experiments did not materially affect the quantity or the quality of the gas evolved.

A portion of the defective ingot was reheated to 1200° C., after which a 47.34-gramme sample of the ingot was heated to 827° C. in a vacuum for nine days. Fifty-two and ninety-four hundredths c.c. of gas, or 8.78 c.c. of gas per cubic centimetre, was evolved.

Samples were then cut from an ingot of soft steel before and after rolling. The composition of the steel was given as follows:

Element	Percentage
Carbon	0.13
Silicon	.011
Manganese	.37
Sulphur	.053
Phosphorus	.075

When heated in a vacuum to a temperature of about 950° C., the sample taken before rolling evolved 6.32 c.c. of gas per cubic centimetre of metal (Table VIII); the sample taken after rolling evolved 3.2 c.c. of gas per cubic centimetre of metal (Table IX). It was therefore concluded that mechanical work, such as rolling, did not change the composition of the gas evolved, but that it diminished the volume of the gas about 50 per cent.

Baker then determined the critical points of soft steel *in vacuo* with the following results:

Ac_1—722	Ac_2—758	Ac_3—867
Ar_1—682	Ar_2—760	Ar_3—846

The relation between these points is shown in the curves on page 338.

Baker's conclusions were as follows:

1. The amount of carbon monoxide evolved from steel is not proportional to the carbon in the steel.

2. There is no appreciable dissociation pressure, such as we should expect to find if carbon monoxide and hydrogen were due to the decomposition of compounds of iron with these gases.

3. Gases are imprisoned in the pores of steel, and, when the

TABLE VI

BAKER.

Steel without Blowholes. Weight 69.31 Grammes.

Temp. C.		Volume in Cubic Centimetres					Percentage Composition.				
		CO_2	H_2	CO	CH_4	N_2	CO_2	H_2	CO	CH_4	N_2
519	6.53	0.07	6.37	0.07	0.02	0.00	1.07	97.57	1.07	3.30	0.00
600	10.67	.19	8.44	2.00	.07	.00	1.78	79.00	18.74	.65	.00
672	12.87	.35	8.07	4.40	.07	.00	2.71	62.70	34.18	.54	.00
688	22.91	.75	6.96	15.02	.12	.03	3.27	30.38	65.56	.52	.13
719	12.61	.07	4.74	7.72	.06	.01	.55	75.58	61.22	.47	.08
765	6.71	.02	3.35	3.26	.05	.02	.29	49.92	48.58	.74	.29
802	4.29	.00	2.24	1.97	.08	.00	.00	52.21	45.92	1.86	.00
865	4.59	.05	2.24	2.22	.08	.00	1.00	48.80	48.36	1.74	.00
936	5.04	.03	2.53	2.42	.07	.00	.59	50.19	48.01	1.38	.00
979	5.64	.01	2.83	2.75	.04	.00	.17	50.17	48.75	.70	.17
T't'l	91.86	1.54	47.77	41.83	.66	.01					

Steel with Blowholes. Weight, 63.261 Grammes.

530	3.28	0.09	3.04	0.06	0.05	0.04	2.74	92.68	1.82	1.52	1.22
603	2.96	.06	2.70	.08	.06	.06	2.02	91.21	2.70	2.02	2.02
681	4.36	.06	2.16	2.01	.15	.03	1.37	48.39	46.10	3.45	.69
696	5.45	.02	1.49	3.85	.05	.04	.36	27.34	70.64	.91	.73
720	5.04	.03	1.84	3.11	.06	.00	.59	36.50	61.70	.19	.00
762	3.80	.02	1.87	1.81	.09	.01	.52	49.21	47.63	2.37	.26
825	3.98	.02	2.01	1.87	.07	.01	.50	50.50	46.98	1.75	.25
893	4.24	.03	2.18	1.93	.10	.00	.71	51.41	45.51	2.35	.00
944	4.48	.02	2.32	2.08	.05	.01	.45	51.78	46.42	1.11	.22
1016	4.50	.02	3.38	1.05	.05	.00	.44	75.11	23.33	1.11	.00
T't'l	42.09	.37	22.99	17.85	.73	.20					

Baker-Steel in the Platinum Boat. Weight, 40 Grammes.

Temp. C.		Volume of the Gas in Cubic Centimetres.					Composition of the Gas in Per Cent.				
		CO_2	H_2	CO	CH_4	N_2	CO_2	H_2	CO	CH_4	N_2
509	3.98	...	3.90	.01	...	.07	0.00	97.99	0.25	0.00	1.75
642	6.37	.06	5.98	.02	.25	.06	.94	93.87	.31	3.92	.94
664	6.18	.15	4.60	1.13	.27	.03	2.42	74.43	18.28	4.35	.49
703	7.75	.33	3.97	3.13	.26	.06	4.26	51.22	40.38	3.35	.77
727	10.72	.32	3.34	6.85	.21	.00	2.98	31.15	63.89	1.95	.00
758	12.06	.18	2.61	9.04	.21	.02	1.49	21.64	74.95	1.74	.16
800	6.61	.02	2.93	3.33	.28	.05	.30	44.32	50.37	4.23	.76
889	5.12	.00	2.55	2.39	.12	.06	.00	49.80	46.68	2.34	1.18

TABLE VI.

Baker-Steel after Re-heating. Weight, 47.34 Grammes.

Temp. C.	Volume of the Gas in Cubic Centimetres.						Composition of the Gas in Per Cent.				
		CO_2	H_2	CO	CH_4	N_2	CO_2	H_2	CO	CH_4	N_2
481	4.66	.01	4.52		0.01	0.03	0.21	96.99		2.14	.64
583	4.50	.01	4.34		.14	.01	.22	96.44		3.11	.22
640	5.57	.06	4.43	.86	.19	.03	1.07	79.53	15.44	3.41	.54
680	5.63	.13	3.20	2.06	.23	.01	2.31	56.83	36.58	4.08	.17
729	11.22	.29	4.47	5.89	.41	.16	2.58	39.84	52.49	3.65	1.42
775	11.44	.14	2.64	8.30	.29	.07	1.22	23.07	72.55	2.53	.62
827	9.92	.11	2.58	6.91	.28	.04	1.10	26.00	69.65	2.82	.41
903	5.51	.00	2.86	2.38	.24	.03	.00	51.90	43.19	4.35	.54
978	8.09	.02	3.81	4.09	.16	.01	.24	47.09	50.55	1.93	.12

TABLE VII.

Baker—Results of Previous Three Tables and Average Analyses of Gas.

Wt. of Steel. g.	Cond. of Steel.	Max. Temp. C.	Vol. of gas, cc.	Vol. of gas per g.	Average Per Cent. Composition. CO_2	H_2	CO	CH_4	N_2
69.31	Contact with tube	802	79.65	1.14	1.89	52.43	44.97	.58	.07
40.00	In Platinum boat	800	53.67	1.34	1.34	50.76	43.93	2.76	.54
47.34	Reheated and in contact with tube	827	52.94	1.11	1.42	49.67	45.57	2.65	.69

TABLE VIII.

Baker—Ingot, C. 13 Per Cent., Weight, 66.6573 Grammes.

Temp. C.	Volume of the Gas in Cubic Centimetres.						Composition of the Gas in Per Cent.				
	Sum	CO_2	H_2	CO	CH_4	N_2	CO_2	H_2	CO	CH_4	N_2
411	2.79	0.04	2.68	....	...	0.07	1.43	96.05	....	...	2.51
525	2.37	.01	2.33		.01	.02	.42	98.31	.42		.84
609	6.05	.01	5.90	.13	.01	.00	.16	97.52	2.15	.16	.00
667	4.92	.08	4.58	.27	.01	.00	1.62	93.09	5.48	.19	.00
720	7.26	.31	3.64	3.29	.02	.00	4.27	50.13	45.31	.27	.00
786	17.19	.24	5.24	11.63	.07	.00	1.40	30.48	67.65	.40	.00
836	13.20	.10	4.19	8.67	.13	.11	.76	31.74	65.68	.98	.83
885	7.03	.01	3.33	3.54	.13	.02	.14	47.37	50.35	1.84	.28
965	8.03	.01	3.99	3.89	.13	.01	.12	49.68	48.44	1.61	.22

TABLE IX.

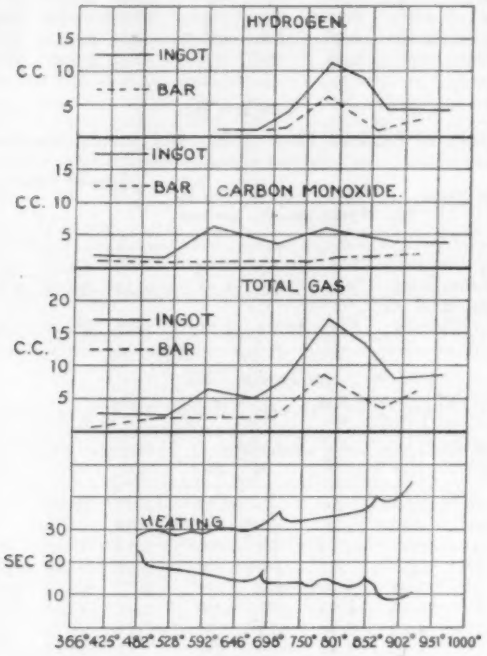
Baker—Bar of Steel. Weight, 67.7358 Grammes.

Temp. C.	Volume of the Gas in Cubic Centimetres.						Composition of the Gas in Per Cent.				
	Sum	CO_2	H_2	CO	CH_4	N_2	CO_2	H_2	CO	CH_4	N_2
435	1.61	0.06	1.46	0.02		0.07	3.72	90.68	1.24		4.34
535	2.21	.02	2.14	...		.05	.91	96.83	....		2.26
610	1.85	.00	1.71	.09		.05	.00	92.43	4.86		2.70
679	2.35	.02	1.80	.42	.02	.09	.85	76.59	17.87	.85	3.83
722	2.75	.03	1.43	1.25	.00	.04	1.09	52.00	45.45	.00	1.45
788	9.14	.11	2.48	6.48	.00	.07	1.20	27.13	70.89	.00	.76
823	7.13	.07	2.43	4.55	.01	.07	.98	34.08	63.81	.14	.98
872	3.96	.02	1.81	2.09	.01	.03	.50	45.70	52.78	.25	.76
927	5.25	.00	2.48	2.60	.00	.17	.00	47.23	49.52	.00	3.23

steel is reheated *in vacuo,* they are driven out. This conclusion is based on the following facts:

(*a*) Hydrogen and carbon monoxide, of which the gas is almost entirely composed, are evolved in the order of their densities. In the case of diffusion the evolution would occur in this manner.

(*b*) The largest quantities of gas are evolved at the critical



Baker.

points. Molecular agitation would tend to increase the rate of evolution.

(*c*) Drilling with blunt drills causes more gas to be evolved than does drilling with sharp drills.

(*d*) Mechanical operations, such as rolling, greatly decrease the quantity of gas retained.

Practically all of the investigators named so far worked with iron and steel. Guillemin and Delachanal,[26] however, obtained a

[26] *Compt. rend.*, 151, 1910, pp. 881–883; *Metallurgie*, 8, 1911, pp. 338–339.

number of results with copper alloys, brass, and tin. Special metals of French, German, and Belgian manufacture were investigated at 1000° C., with the following results:

Material	Gas volume / Metal volume	Per cent. CO_2	Per cent. H	Per cent. CH_4	Per cent. CO	Per cent. N
Special brass	1.12	1.9	91.53	2.38	3.56	0.63
Special brass	.84	.3	79.1	1.4	17.9	1.3
Special brass	26.00	8.7	59.9	1.3	29.5	.6
Al brass	24.2	2.06	95.84	.6	.9	.6
Wrought brass	2.3	2.3	92.6	2.3	.2	2.6
Wrought brass	.43	3.2	93.3	1.2	1.1	1.2
Bronze	7.3	16.2	59.9	7.2	16.4	.3
Bronze	.78	86.7	13.0	.....	.....	.3
Phosphor bronze	.28	58.0	40.8	.....	.....	1.2
Commercial Sn	.19	14.5	63.0	5.4	12.3	4.8
Gray Sn	.21	14.7	71.7	4.9	.5	8.2

From the results just given, these investigators arrived at the following conclusions:

1. The special wrought brass evolved particularly large volumes of gas (1 to 30 times the volume of the metal used), and this gas consisted mostly of hydrogen, carbon dioxide, and carbon monoxide.

2. In perfect castings the gas was composed chiefly of hydrogen, this constituting 90 per cent. of the total volume evolved.

3. In the imperfect alloys, in addition to hydrogen, much carbon monoxide and some carbon dioxide were found.

4. The forged pieces contained less gas than the cast pieces.

5. In the case of perfect pieces of wrought brass, the occluded hydrogen seemed to have no undesirable effect on the mechanical properties of the alloys.

6. Phosphor bronze contained less gas, particularly hydrogen and carbon monoxide, than did the other alloys. (Phosphorus always hinders the solution of hydrogen in metals.)

7. Commercial tin contained only a small volume of gas, made up of carbon dioxide, carbon monoxide, and hydrogen.

Dr. P. L. T. Heroult[27] has expressed the following opinion concerning the origin of the gases found in steel:

"Blowholes in steel ingots invariably contain hydrogen and nitrogen, often with only traces of carbon monoxide. On the

[27] *Trans. Am. Electrochem. Soc.*, **17**, 1910, pp. 135–137.

other hand, it is well known that when a thoroughly sound steel ingot is placed in a vacuum chamber a certain amount of the above-named gases will be exhaled or thrown off." He then adds that, "although it is popularly thought that the amount of gases in steel depends upon the process used in preparing the steel, nevertheless, this is an erroneous impression, since the quantities of gases evolved from different kinds of steel are about the same."

Finally he says: "Blowholes are the result of disengagement of carbon monoxide, with the exception, of course, of accidental blowholes due to the poor condition of the moulds.

"This carbon monoxide does not preëxist in the steel: it is only produced when the steel cools down and part of it has become solid. Steel that will produce blowholes contains, in the molten state, carbon and, at the same time, iron protoxide. So long as the steel is molten and hot, these two bodies can be kept apart, and for each temperature and composition of steel there is a state of equilibrium at which no chemical reaction takes place. The heat is then what the Germans call 'gar'; that is to say, 'dead-melted.' If the temperature is increased, the reducing action of carbon will be intensified and carbon monoxide will be evolved. If, on the contrary, the temperature is lowered, nothing happens until the steel gets partially solidified, with the effect that carbon and iron protoxide are crowded into a small space with what we might call the mother-liquor, and monoxide of carbon is evolved. The blowholes produced are filled with carbon monoxide at a high temperature. As this gas cools down, however, it creates a vacuum, and we then repeat the conditions of the ingot in the vacuum chamber.

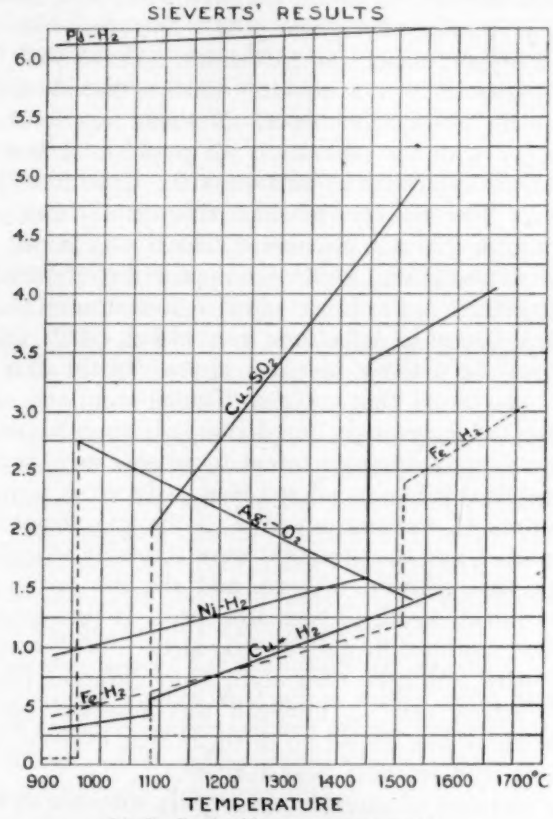
"You can understand now why it is that blowholes are found containing hydrogen and nitrogen. Steel does not contain any gases to amount to anything, and whatever small quantities it does contain are not injurious or detrimental to its quality. As a matter of fact, Bessemer steel, either acid or basic, which has every possible opportunity of absorbing gases, does not contain any more than any other steel."

An interesting research on the solubility of gases in metals was conducted by Dr. A. Sieverts.[28] He sought to determine: (1) The influence of temperature on the solubility of gases at constant, atmospheric pressure; (2) the diffusion of gases through

[28] *Zeit. für Elektrochemie*, 16, 1910, pp. 707–713.

metals; (3) the influence of the surface of metals on the solubility of gases; (4) the influence of the addition of a second metal on the solubility of gases; (5) the relation between solubility and gas pressure.

In making his determinations, Sieverts brought gases into con-



Mg H_2 dissolved by 100 grammes metal.
Mg O_2 6.5 dissolved by 1 gramme Ag.
Mg SO_2 dissolved by 0.5 gramme Cu.

tact with metals under different temperatures and pressures, and then measured the volume of gas absorbed. The means by which this operation was carried out were not disclosed. For temperatures up to 1350° C. a platinum foil oven was used; for temperatures between 1350° and 1700° C. a silundum furnace was used. Tubes of biscuit porcelain were also found to be suffi-

ciently impervious to gases at temperatures above 1400° C. to introduce no serious error in numerical results.

The results of Sieverts's experiments were many and varied. It was discovered that a number of metals, tested in both solid and molten states, dissolved neither nitrogen nor hydrogen. This list of metals included cadmium, thallium, zinc, lead, bismuth, tin, antimony, aluminum, silver, and gold. Nitrogen was especially insoluble in copper, nickel, and palladium. Above 800° C. aluminum was found to form a nitride. Carbon dioxide and carbon monoxide were insoluble in copper. Methane was decomposed by molten copper with the separation of graphitic carbon. Above 1000° C. nickel absorbed carbon monoxide. Iron acted in a similar manner. The manner in which this carbon monoxide was held in solution was not discovered, but it was hoped that this might be disclosed later. Hydrogen appeared to possess the most general solubility. It was found possible to determine the amounts of hydrogen present in palladium, iron, nickel, cobalt, and copper. Oxygen could be detected in silver alone. In the case of other metals it was found that oxygen formed solutions of oxides, which possessed exceedingly low decomposition voltages. In special cases only was nitrogen found to possess any marked solubility in metals. When powdered iron, reduced in nitrogen, was heated to 900° C. varying amounts of the gas, dependent upon the temperature and the pressure, were suddenly absorbed. The metal was then allowed to cool, and the gas was evolved at 900° C. as quickly as it had been absorbed. It thus appeared that nitrogen was absorbed by gamma iron alone. With commercially pure iron wire and with electrolytic iron different results were obtained. Above 900° C. nitrogen was absorbed very slowly. When the metal was cooled no nitrogen was evolved, indicating that a nitride had probably been formed.

In the majority of cases in which gases were found to be soluble in metals the solubility increased very rapidly with the temperature. This increase was directly proportional to the rise in temperature. The systems copper-hydrogen, iron-hydrogen, nickel-hydrogen, and copper-sulphur dioxide were examples of cases with which this increase occurred. There were, however, some exceptions to the rule. With the system silver-oxygen, for instance, small amounts of the gas were dissolved by the solid silver. When the melting-point of silver was attained, a large

volume of oxygen was absorbed, and the solubility then decreased with a rise in temperature.

Sieverts next investigated the ability of gases to diffuse through metals. It was discovered that oxygen would diffuse through silver, and that hydrogen would diffuse through platinum. In the latter case little or none of the gas was absorbed. It was also determined that hydrogen would not diffuse through aluminum, and that carbon monoxide would not diffuse through copper. In this respect, sulphur dioxide acted similarly to carbon monoxide. At 1000° C. carbon monoxide appeared to diffuse through nickel and iron to a very slight extent.

In determining the effect produced on the solubility of gases in metals by differences in the surfaces exposed to the gases, nickel in the form of solid pieces, wire, and powder was saturated with hydrogen. It was determined that equal weights of the three different forms of the metal absorbed equal volumes of the gas. The same result was obtained when iron, copper, and palladium in different forms were exposed to gases.

It was also determined that the solubility of gases in alloys was equal to the average solubilities of the gases in the constituents of the alloys; that is, as much gas was absorbed by an alloy as was absorbed by the separate constituents of the alloy.

From the foregoing results Doctor Sieverts deduced the following general rule for determining the amounts of gases dissolved by metals: The absorbed mass (m) is proportional to the square root of the pressure (p); or $m = p \times$ const.

This rule was proved for the following systems:

Hydrogen and (palladium, solid; nickel, solid and molten; iron, molten; copper, molten; copper alloys, molten).

Oxygen and (silver, molten; gold-silver, molten).

Nitrogen and (gamma iron, solid).

Sulphur dioxide and (copper, molten).

Attention is directed to the close analogy between the above formula of Sieverts and the van't Hoff hypothesis: $C_1 = C_2^n \times$ const. Curves showing the numerical results of the preceding investigations are shown in the following diagram.

G. Charpy and S. Bonnerot[29] discovered that certain samples

[29] *Compt. rend.*, **152**, 1911, pp. 1247–1250.

of steel evolved gas when heated to 950° C. in a vacuum. In their first series of determinations steel manufactured by the Siemens-Martin process was used in the two forms: plates two millimetres in diameter, and 0.1 millimetre turnings. Gas was evolved, as shown in the following table:

Time of heating	*dv/dt* in c.c. per gramme per hour		Total volume gas per gramme	
	Plate	*Turnings*	*Plate*	*Turnings*
After ½ day	0.01	0.06	0.03	0.16
After 1½ days	.025	.015	.25	.29
After 2½ days	.008	.008	.33	.37
After 3½ days	.003	.003	.36	.40

The following table shows the results obtained in later determinations:

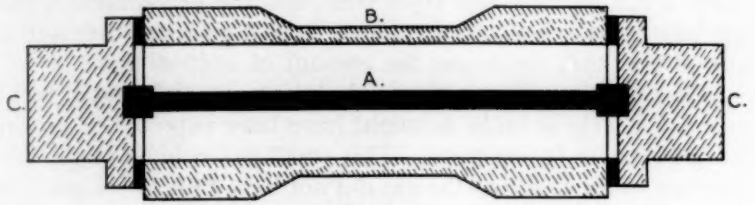
Material	Per cent. by volume of gas obtained	
	After 5 hours	After 3½ days
Steel (0.9 per cent. C.)	0.65	0.98
Steel (1.05 per cent. C.)	.55	.75
Steel (1.2 per cent. C.)	.53	.69
Steel (1.0 per cent. C.)	.24	.31
Steel	.29	.34
Steel (0.07 per cent. C.)	.40	.70
Steel (0.04 per cent. C.)	.79	1.06

It will be noticed that the gas volumes obtained in these experiments were comparatively small.

In 1912, G. Wesley Austin,[30] of the University of Birmingham, published a method for the determination of occluded gases very similar to the method finally designed by Parry over thirty years before. Having concluded that the chief error in former investigations lay in the fact that the material used in the determinations was not fused, and that thus there was no means of telling whether or not all the gas was evolved from the metal, he perfected an apparatus by means of which his samples could be fused in a vacuum. The necessary high temperature was attained by passing an alternating current of 1000 to 20,000 ampères directly through the samples. By this method it was found possible

[30] *Jour. of Iron and Steel Inst.*, **86**, 1912, 2, pp. 236–240.

to gradually increase the temperature until the metal fused. Below is given a sketch of Austin's apparatus:



A. Specimen. *B*. Steel tube. *C*. Cu electrodes.

"The envelope of the furnace was a (weldless) steel tube, 20 cm. long, 9 cm. in internal diameter, and 2 cm. thick. The tube was closed by flanged copper electrodes forced against the ends of the tube by large, hollow steel nuts. The contact surfaces were machined and cut with fine V-grooves, into which insulating packing was compressed. The electrodes were water-cooled, and a seamless capillary copper tube, screwed and sweated into the steel pipe, connected the interior with the vacuum pump.

"The specimens examined were turned from round bars 1 inch in diameter and 8¾ inches long. The middle 6 inches of these bars was turned down to ½ inch in diameter, this being the portion which it was intended to fuse. It was found that practically all of this 6 inches could be fused if, when the melting-point was approached, the current was shut off for a few moments and then thrown on again, thus allowing the heat to distribute itself along the bar. Each heating was conducted in three stages of one-half hour each, the first stage being to 900° C., the second stage to 1100° C., and the third stage to fusion. From this procedure the following results were obtained."

Material	Analysis (per cent.)					Gas analysis (per cent.)			Quantity of gas
	C	Si	Mn	S	P	CO_2	CO	H, N, etc.	c.c. per gramme
Cast iron	3.5	2.50	.60	.05	1.50	3.1	23.0	73.9	0.27
Crucible steel	1.1	.24	.39	.02	.02	.4	44.2	55.4	1.73
Medium	.49	.35	.72	.02	.02	.6	45.1	54.3	1.35
Open-hearth mild steel	.09	.05	.75	.05	.05	*5.6	31.5	62.9	.66 = .97
						†.7	43.0	46.3	.31
Bessemer steel	.05	.09	.29	.06	.05	*5.2	59.8	35.0	.87
						†3.8	43.5	52.7	

* Extracted during first stage of heating.
† Extracted during remaining stages.

From the results of his investigations Austin arrived at two conclusions: the volume of gas evolved from cast iron is relatively much smaller than from steel, and the percentage of carbon monoxide is considerably lower; the higher the carbon content of the steel, the larger the amount of evolved gas.

The volumes of gas obtained during Austin's experiments were not nearly so large as might have been expected in heating the metal to its fusing-point. This small gas volume might have been due to the fact that the gas did not have time to escape from the test bars, the fusing of the metal naturally resulting in a sudden lowering of the temperature, due to the break in the circuit. There was another source of error in the steel envelope surrounding the test bars. Part of the gas obtained might easily have been evolved from this envelope instead of from the bars, and part of the gas liberated from the bars might easily have been absorbed by the steel envelope and also by the unfused portion of the bar.

About this time (1913) Dr. W. Herwig[31] became interested in the question of nitrogen in iron. The blisters formed on plates during rolling and annealing were examined and were found to contain 90 per cent. of nitrogen. Nitrogen was determined by a modification of the Kjeldahl process. It was concluded that the gas present in the blisters had come from the iron and not from the air, and that, in the iron, it was present in the combined form. Twenty grammes of steel turnings, when heated to 800° C. for 12 hours in a stream of hydrogen, evolved both nitrogen and ammonia. The nitrogen content of the turnings fell from 0.018 per cent. to 0.002 per cent.

Experiments were conducted with the object of determining the gases which had been retained by liquid cast iron.

(*a*) Twenty grammes of white pig iron of the following composition was used:

Element	Percentage
Carbon	2.61
Phosphorus	1.61
Manganese	.67
Sulphur	.162
Nitrogen	.009
Silicon	.31

[31] *Stahl u. Eisen*, 33, 1913, pp. 1721–1727.

When this iron was heated to 900° C. for 5 hours in a porcelain tube, 18 c.c. of hydrogen and 8 c.c. of carbon monoxide were evolved.

(*b*) Twenty grammes of gray pig iron of the following composition was heated:

Element	Percentage
Carbon	3.17
Phosphorus	1.97
Manganese	1.42
Silicon	.92
Sulphur	.026
Nitrogen	.004

When this iron was heated under conditions similar to the conditions under which the white pig iron had been heated, 7.4 c.c. of hydrogen and 0.8 c.c. of carbon monoxide were evolved. In both cases small quantities of carbon dioxide and of oxygen were also evolved. The gases were evolved irregularly, small explosive evolutions occurring at the "arrest points" on the cooling curves.

Steel turnings, when heated in pure nitrogen, did not absorb any gas, but when heated in a mixture of hydrogen and nitrogen the nitrogen content of the steel rose to a maximum point beyond which it seemed impossible to pass. In some experiments the maximum nitrogen content ranged from 0.032 to 0.052 per cent. for different samples. The presence of nitrogen in basic steel was thus explained by the supposition that a combination of the nitrogen in the blast and the hydrogen in the pig yielded ammonia. This gas was in turn decomposed by the steel, yielding iron nitride.

Herwig's numerical results were, on the whole, much lower than the results obtained by a number of previous investigators.

In 1910[32] P. Goerens conducted a number of investigations on occluded gases, using a quartz tube heated electrically by a Heræus resistance oven to 1100° C. He noted the importance of keeping the iron out of contact with the quartz, since at 950° C. a very noticeable reaction between these two materials occurs. The materials on which the investigations were conducted were in the form of filings. Temperatures were measured by means of a Le Chatelier pyrometer. Goerens used 36 different kinds of iron

[32] *Metallurgie*, 7, 1910, pp. 384–395.

TABLE X.

Showing Goerens' Results.

No. of Det.	Temp. C.	Time heated min.	Weight of metal G.	Gas vol. in c.c. at 0° and 76 mm.	Vol. of gas per vol. of Fe. c.c.	Composition of metal in per cent.					Composition of gas in per cent.				C.c. of gas per c.c. of metal			
						P	Mn	C	S	Si	CO_2	CO	H_2	N_2	CO_2	CO	H_2	N_2
1	850 880	20	30.29	4.74	0.88	0.074	0.23	0.05	0.057	0.019	20.1	42.1	24.2	13.6	0.18	0.37	0.21	0.12
2	900 950	15	22.17	9.52	3.38	.079	.4	.067	.038	.021	7.75	76.3	6.0	9.95	.26	2.58	.20	.34
3	900 950	15	12.9	4.94	3.01	.079	.4	.067	.038	.021	4.9	74.9	6.5	13.7	.15	2.36	.20	.55
4	900 930	15	18.21	4.51	1.95	.103	.28	.056	.066	.014	13.8	45.1	31.8	9.3	.27	.88	.62	.18
5	900 930	15	20.22	11.56	4.1	.103	.49	.083	.05	.05	14.7	65.1	12.2	8.0	.60	2.67	.50	.33
6	900	15	13.74	2.51	1.44	.07	.25	.039	.062	.008	9.7	51.8	25.5	13.0	.14	.75	.37	.19
7	900 940	20	9.62	4.03	3.30	.072	.39	.072	.049	.007	8.8	69.9	11.0	10.3	.27	2.46	.39	.41
8	890 910	30	12.19	2.04	1.2	.072	.39	.072	.049	.007	.3	75.9	11.1	12.7	.004	.91	.13	.16
9	880 890	25	17.51	3.34	1.5	.086	.37	.075	.051	.015	6.5	76.6	11.3	5.6	.10	1.15	.17	.08
10	900 925	30	17.88	6.85	3.9	.112	.89	.302	.037	.021	1.5	77.2	4.5	16.8	.06	3.01	.18	.65
11	900 940	30	20.57	1.55	.59	.086	.28	.043	.074	.013	9.5	64.1	15.9	10.5	.06	.37	.09	.07
12	900	30	17.6	10.98	4.4	.106	.43	.190	.065	.017	4.3	79.7	3.5	12.5	.19	3.51	.15	.55
13	900 960	15	9.15	2.61	2.1	.103	.28	.056	.066	.014	24.8	46.5	17.4	11.3	.52	.98	.37	.24
14	950 980	12	7.67	2.64	2.7	.....	.49	.083	.050	.05	5.8	73.4	7.8	13.0	.16	1.98	.21	.35

15	1000	15	9.08	1.4	1.2	.068	.288	.036	.064	.01	9.9	68.2	20.1	1.8	.12	.82	.24	.02
16	900	15	9.99	2.67	2.1	.077	.476	.056	.053	.016	1.1	....	22.2	.....	.02	....	.47	....
17	930 960	20	10.58	4.79	3.6	.077	.475	.056	.053	.016	10.4	68.5	9.2	11.9	.37	2.45	.33	.44
18	930	15	10.00	3.68	2.5	.077	.476	.056	.053	.016	9.5	65.1	12.0	13.3	.22	1.63	.30	.35
19	900 930	30	14.79	2.43	1.3	.085	.12	.058	.043	.017	7.5	80.1	7.1	5.3	.10	1.04	.08	.07
20	900	30	32.66	6.49	1.3	.069	.12	.076	.031	.023	6.4	84.8	4.7	4.1	.08	1.10	.05	.06
21	900 930	0	13.18	3.30	1.9	.098	.22	.15	.042	.169	4.7	78.3	11.7	5.3	.69	1.49	.22	.10
22	900	35	16.79	3.56	1.7	.025	.30	.093	.054	.003	2.2	85.6	7.4	4.8	.04	1.44	.12	.10
23	900	30	18.99	4.49	1.9	.031	.93	.138	.037	.35	3.4	82.8	8.1	5.7	.06	1.57	.15	.12
24	850	20	9.60	1.92	1.6	.040	.93	.138	.037	.35	3.8	74.9	13.9	7.4	.06	1.20	.22	.12
25	900	20	9.91	1.09	.85	.045	.93	.142	.039	.236	1.7	58.4	15.4	14.5	.01	.58	.13	.13
26	900	30	15.27	3.3	1.7	.018	.39	.108	.039	.003	5.0	78.5	7.4	9.1	.09	1.33	.13	.15
27	900 930	15	13.5	3.18	1.8	.023	.60	.114	.033	.003	2.6	83.2	4.7	9.5	.05	1.5	.09	.16
28	900 930	25	16.74	6.98	3.3	.024	.58	.112	.031	.001	4.2	81.7	10.2	3.9	.14	2.7	.34	.13
29	910 930	20	14.62	3.15	1.7	.045	.49	.14	.052	.006	5.4	79.4	6.3	8.9	.09	1.35	.10	.16
30	900 930	15	15.45	3.44	1.7	.045	.77	.175	.041	.007	4.5	79.8	5.6	10.1	.08	1.36	.10	.16
31	910	20	13.75	3.96	2.3	.049	.65	.137	.042	.011	3.5	78.6	6.7	11.0	.08	1.81	.15	.26
32	930 970	15	11.64	4.87	3.0	.038	.43	.40	.006	.153	W. .24	.8	81.6	6.1	11.5	.02	2.45	.18	.35
33	920 960	15	9.15	2.25	1.9	.038	.43	.40	.006	.153	.24	1.3	69.2	18.6	10.9	.02	1.31	.35	.22
34	950 960	15	9.47	1.78	1.5	.031	.34	.42	.005	.155	.57	.7	71.6	7.2	20.5	.01	1.07	.11	.31
35	900	35	18.15	14.3	6.1	.....	.....	.....	.....	.....		3.7	72.7	8.3	15.3	.22	4.45	.51	.92
36	850	20	16.23	17.05	8.2	.090	.085	3.65	.005	.014		11.5	70.5	11.1	6.9	.95	5.80	.91	.56

Note.—Description of material on next page.

DESCRIPTION OF THE MATERIAL USED BY GOERENS.

Thomas Iron—Charge No. 1.

No. 1. Before the addition of ferromanganese.

No. 2. After the addition of ferromanganese.

No. 3. After the addition of ferromanganese, after the same had been poured 4 minutes.

Thomas Iron—Charge No. 2.

No. 4. Same as No. 1.

No. 5. Same as No. 2.

Thomas Iron—Charge No. 3.

No. 6. Same as No. 1.

No. 7. Same as No. 2.

No. 8. Same as No. 3—poured 8 minutes.

Thomas Iron—Charge No. 4.

No. 9. Same as No. 1.

No. 10. Same as No. 2—after addition of ferromanganese and spiegel.

Thomas Iron—Charge No. 5.

No. 11. Same as No. 1.

No. 12. Same as No. 2.

Thomas Iron—Charge No. 6.

No. 13. Same as No. 1.

No. 14. Same as No. 2.

Thomas Iron—Charge No. 7.

No. 15. Same as No. 1.

No. 16. Same as No. 2.

No. 17. Same as No. 2—taken from upper part of sample.

No. 18. Same as No. 2—taken from under part of sample.

Electro-Steel.

No. 19. After the removal of hammer scale.

No. 20. After the removal of the second scale of ferrosilicon.

No. 21. Determination on prepared steel.

Siemens-Martin Iron—Charge No. 1.

No. 22. Shortly before addition of ferromanganese.

No. 23. Shortly after addition of ferromanganese—ferrosilicon added in mold.

No. 24. After the preparation at pouring of first block.

No. 25. After the preparation at pouring of last block.

Siemens-Martin Iron—Charge No. 2.

No. 26. Shortly before preparation.

No. 27. Shortly after preparation.

No. 28. Shortly after preparation—at pouring of the last block.

Siemens-Martin Iron—Charge No. 3.

No. 29. Same as No. 26.
No. 30. Same as No. 27.
No. 31. Same as No. 28.
No. 32. Crucible steel, unpurified—Charge No. 1.
No. 33. Crucible steel, unpurified—Charge No. 1.
No. 34. Crucible steel, unpurified—Charge No. 2.
No. 35. Determination on rail.
No. 36. Swedish pig iron.

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and steel in his investigations, and determined that the ratio of the volume of gas obtained to the volume of the metal used varied from 0.88 to 8.2, averaging, however, from 1.7 to 3.0. Seventy to eighty per cent. of this gas was carbon monoxide, 5 to 15 per cent. was hydrogen, and 7 to 14 per cent. was nitrogen. Table X (pp. 348 and 349) gives these results in detail. Goerens believed that the carbon monoxide evolved was due to the action of the carbon and oxygen originally present in the steel as carbide and as oxide. In proof of this theory he performed the following experiment:

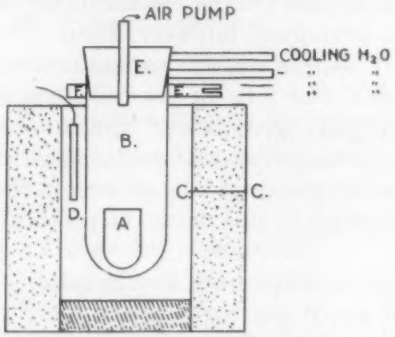
Some strongly oxidized iron, low in carbon, was heated in a vacuum until no more gas was evolved, and a sample of iron containing 3.6 per cent. carbon was treated similarly. The two samples were then mixed and heated in a vacuum, whereupon large volumes of carbon monoxide were at once evolved. Since such an action occurred at high temperatures, it was considered probable that it would occur to a certain extent even at ordinary temperatures.

In making the analysis of the gases driven off, the carbon dioxide was determined by absorption in potassium hydrate solution, the hydrogen and carbon monoxide were determined by explosion, and the nitrogen was determined by difference (see Table X, pp. 348 and 349).

Recently Goerens and Paquet[33] arrived at the same conclusion that Austin reached, namely, that all the gas could not be driven from metals unless the materials were fused. They therefore endeavored to determine some means by which iron and steel could be completely fused in a vacuum. Knowing that impurities lower the melting-point of iron, they decided to alloy iron with some substance which would reduce the melting-point to an easily attainable temperature. After experimenting with various

[33] *Ferrum*, 12, 1915, pp. 57–64; 73–81.

metals, they concluded that the metals most suitable for their purpose were Kahlbaum's tin and antimony. When blank tests were conducted with these two metals, it was discovered that 100 grammes of antimony contained only 0.5 c.c. of gas, and that 100 grammes of tin contained only 0.6 c.c. of gas. In conducting determinations with iron and steel, 0.3 gramme of iron or steel, 0.3 gramme of antimony, and 3 grammes of tin were mixed in a crucible of magnesia and placed in a quartz tube, which was evacuated and heated electrically to 1150° C. for about two hours. Below is a sketch of the apparatus used:



A. Mg crucible. *B*. Quartz tube. *C*. Elec. res. oven. *D*. Thermoelement. *E*. Stopper H_2O cooled. *F*. H_2O cooled ring.

In the first series of determinations a sample of iron of the following composition was used.

Element	Percentage
Carbon	0.036
Manganese	.288
Phosphorus	.068
Sulphur	.064
Silicon	Trace

The following table shows the results obtained:

Experiment number	Location of sample in test piece	c.c. of gas per 100 grammes iron	Percentage of gases by weight			
			CO_2	CO	H_2	N_2
A.	Edge	46	0.0027	0.0320	0.0010	0.0129
D.	Edge	46	.0056	.0312	.0010	.0122
B.	Middle	70	.0085	.0393	not determined	not determined
E.	Middle	54	.0100	.0305	.0017	.0100
C.	Edge	44	.0053	.0235	.0014	.0103
F.	Edge	41	.0100	.0247	.0008	.0103
G.	Edge	43	.0061	.0291	.0008	.0117

In a later group of experiments, using this method for liberating occluded gases, about 75 determinations were made with various kinds of iron and steel. The ratio of gas volume to metal volume was found to vary from 1 to 9, carbon monoxide forming the largest constituent, both by weight and by volume. A number of the results are tabulated (Table XI).

Thus far in this discussion no mention has been made of the electrolytic hydrogen occluded in metals. Graham[34] first made the observation that the best method of saturating any metal with hydrogen was to make the metal act in dilute acid as the negative electrode of a battery of six Bunsen cells. He gave the name hydrogenium to hydrogen absorbed in this process, and said that hydrogenium appeared to be the active form of hydrogen, just as ozone is the active form of oxygen.

Cailletet[35] decomposed electrolytically a solution of ferrous chloride rendered neutral by ammonia and obtained hard crystals of iron containing 0.028 per cent. of hydrogen.

TABLE XI

The Work of Goerens and Paquet.

Material No. 1—Rolled Molten Iron. Analysis: C, 0.08 per cent.; Mn, 0.4 per cent.; P, 0.082 per cent.; S, 0.048 per cent.

Determination	c. c. of gas per 100 grammes	Gas Analysis in per cent. by weight CO_2	CO	H_2	N_2
No. 1	73	0.009	0.0735	0.00081	0.0058
No. 2	69	.0069	.0691	.00079	.0054
No. 3	68	.0069	.0692	.00051	.0071
No. 4	68	.0082	.0660	.00069	.0071
Average	69.5	.0078	.0694	.00070	.0062

Material No. 2—Rolled Molten Iron. Analysis: C, 0.06 per cent.; Mn, 0.4 per cent.; P, 0.08 per cent.; S, 0.04 per cent.

No. 1	44	0.0098	0.0320	0.00058	0.0110
No. 2	40	.0066	.0325	.00047	.0066
No. 3	40	.0098	.0335	.00059	.0042
No. 4	43	.0053	.0355	.00064	.0078
No. 5	42	.0058	.0346	.00065	.0066
No. 6	43	.0069	.0384	.00059	.0047
Average	42	.0073	.0344	.00050	.0068

[34] *Proc. Roy. Soc.*, 17, 1869, p. 219.
[35] *Compt. rend.*, 80, p. 319.

Goerens and Paquet—Gas Content of Various Commercial Irons.

Material.	Composition of the Metal. C	Mn	P	S	Si			cc. gas per 100 g. Metal.	Composition of the Gas. Per Cent by Weight. CO_2	CO	H_2	N_2	Total
						(a) *Thomas Iron.*							
1	0.05	0.36	0.11	0.045	.....	....	....	22	0.004	0.0196	0.0003	0.0029	0.0268
2	.08	.40	.08	.048	.....	....	....	40	.009	.0352	.0006	.0025	.0383
3	.05	?	.08	.040	.....			41	.0077	.0342	.0006	.0065	.0413
4	.05	.40	.03	.040	.....	....	....	49	.0061	.0393	.0006	.0122	.0521
						(b) *Martin Iron.*							
5	.08	.40	.05	.030	.....			38	.0048	.0341	.0005	.0061	.0455
6	.15	.37	.06	.060	.....			46	.0048	.0410	.0009	.0024	.0443
7	.08	.44	.04	.037	.....			78	.0178	.0785	.0007	.0020	.0812
						(c) *Electro-Steel.*							
8	.19	.50	.02	.012	.42	....	....	10	.0047	.0061	.0002	.0015	.0125
9	.08	.35	.01	.010	.09	4.34	1.10	13	.0082	.0015	.0007	.0000	.0104
10	.10	.38	.011	.010	.07	3.30	....	15	.0064	.0061	.0007	.0000	.0132
11	.15	.49	.011	.012	.45	....	....	25	.0058	.0092	.0012	.0048	.0210
12	.26	.43	.068	.023	.015	....	....	25	.0053	.0098	.0012	.0041	.0214
13	.10	.40	.010	.012	.10	....	....	28	.0053	.0207	.0008	.0019	.0287
14	.45	.38	.018	.022	1.27	....	....	32	.0058	.0167	.0013	.0042	.0280
15	.98	.45	.158	.075	.015	....	....	70	.0043	.0688	.0010	.0083	.0824
16	.71	.37	.018	.016	.23	....	....	73	.0106	.0684	.0010	.0078	.0878
17	1.35	.44	.020	.015	.19	....	.37	88	.0053	.0851	.0010	.0141	.1055
18	.10	.35	.009	.008	.17	3.62	.90	94	.0018	.0569	.0047	.0012	.0646
19	1.16	.38	.017	.016	.18	....	....	94	.0050	.0900	.0011	.0124	.1085
20	.33	.38	.026	.016	.10	3.06	1.94	105	.0109	.0708	.0039	.0056	.0912
						(d) *Crucible Steel.*							
21	.38	.26	.056	.021	.19	....	.65	29	.0090	.0248	.0004	.0024	.0366
22	.84	.36	.041	.017	.15	....	....	41	.0058	.0391	.0007	.0015	.0471
23	.16	.44	.008	.008	.29	4.00	.91	50	.0032	.0271	.0022	.0053	.0378
24	.47	....	.020	.028	.....	2.98	1.29	51	.0200	.0257	.0016	.0068	.0541
25	.97	.14	.....	.010	.12	....	....	79	.0098	.0712	.0017	.0020	.0847
26	.27	.45	.010	.012	.24	4.00	1.30	152	.0096	.1290	.0041	.0082	.1509

William H. Johnson[36] confirmed the experiments of Graham, and in addition determined that occluded hydrogen possesses the property of making the iron or steel which contains it very brittle. As soon as the hydrogen is evolved by heating, the metal regains its former elasticity. Johnson also observed that iron and steel immersed for a time in dilute acids become brittle. He therefore concluded that hydrogen is absorbed in this case as in the former. Iron allowed to remain in dilute acids for five hours gained in weight in hydrochloric acid 0.028 per cent. and in sulphuric acid 0.036 per cent. When the iron which had been removed from the acid solution was heated, hydrogen was evolved, and the weight of the iron returned to a value very close to its former

[36] *Jour. of Iron and Steel Inst.*, 23, 1874–1875, pp. 168–180.

weight. When a stream of hydrogen was allowed to pass over the same iron, little or no hydrogen was absorbed, and the iron did not become brittle. Johnson therefore concluded that hydrogen must be in the nascent state in order to be occluded.

Hughes,[37] Baedeker,[38] and Ledebur[39] have all recorded the observation that iron, when attacked by dilute hydrochloric or sulphuric acids, occludes hydrogen.

Le Blanc,[40] in his researches on decomposition voltages, observed that the values of the decomposition voltages of many elements varied considerably when hydrogen was known to be evolved. In cases in which no hydrogen was evolved, the values of the decomposition voltages were found to be normal.

Roberts-Austen,[41] by galvanic precipitation of a chemically pure solution of ferrous sulphate, *produced a piece of iron, which evolved hydrogen when warmed in water at 70° C.* This evolution of gas ceased after several hours, however, and the iron was then heated in an evacuated porcelain tube, the temperatures being read by means of a Le Chatelier pyrometer. A further evolution of gas occurred, and it was noted that, no matter how long the sample was heated, gas continued to be liberated, although the amounts were very slight indeed by the time a temperature of 1300° C. was obtained. The sample of iron was heated to 1300° C. and allowed to cool several times in succession. The cooling curves were plotted, and it was observed that certain critical points at 261° and 481° C., which were at first present, gradually disappeared with repeated heatings. Roberts-Austen decided that these critical points were due to hydrogen occluded in the metal. The test piece of iron was then made the negative pole of a galvanic cell for a short time. The iron was heated again and the cooling curves plotted as before. It was observed that the upper critical point at 481° C. had been partially restored, but that the lower one was still absent. Roberts-Austen suggested that the upper point had been due to the presence of a hydride and that the lower point had been due to the formation of an eutectic.

[37] *Jour. of Soc. of Telegraph Engin.*, 1880, p. 163.
[38] *Zeit. des Vereins deutscher Ingenieure*, 1880, p. 186.
[39] *Stahl u. Eisen*, 1887, p. 681; 1889, p. 74.
[40] *Zeit. fur physik. Chem.*, **12**, 1893, pp. 333-358.
[41] *Proc. Inst. Mech. Eng.*, 1899, 5th Report Alloys Research Comm., pp. 42-74.

More recently T. W. Richards and G. E. Behr[42] observed that the electromotive force of iron varied with the amount of occluded hydrogen. In their experiments a porcelain tube heated with a Fletcher burner was used. Temperatures were measured with a platinum rhodium thermocouple according to the method of Le Chatelier. These investigators first experimented with iron reduced from iron oxide in a stream of hydrogen gas at 570° C. Iron prepared in this manner was found to possess an electromotive force considerably lower than the normal electromotive force of iron (0.795). Upon heating the iron, hydrogen was evolved, and thus the low electromotive force of the iron was accounted for, since the electromotive force of hydrogen is lower than that of iron. The investigators therefore concluded that the hydrogen was present in the same form as in pure hydrogen gas.

Certain experiments were conducted with the object of ascertaining what change, if any, occurs in the structure of iron when it is suddenly quenched. Test samples were heated to 700° C., allowed to fall through an atmosphere of hydrogen to prevent oxidation, and caught in cold water. Such samples possessed at first an electromotive force 0.15 volt higher than the electromotive force of ordinary iron. When allowed to stand in solutions of ferrous sulphate or of potassium sulphate, or in water, hydrogen bubbles were evolved and the electromotive force slowly receded to normal. This drop occurred most rapidly in the ferrous sulphate solution. Because the same results were obtained when the hot iron was allowed to fall through nitrogen instead of through hydrogen, the theory was advanced that the hydrogen occluded by the iron was formed by the decomposition of the water into which the hot iron fell. Iron serving as a cathode also exhibited this high initial electromotive force, but, on standing, gradually decreased to its normal value. Iron which had stood in a desiccator for one year showed no tendency to reduce potassium ferricyanide, whereas newly prepared iron reduced it at once. Iron heated for a time in hot hydrogen gas exhibited a slightly abnormal electromotive force.

From the results of the investigators described above, Richards and Behr concluded that the high electromotive force found in certain samples of iron was due to hydrogen occluded in the nas-

[42] *Zeit. für physik. Chem.*, **58**, 1907, pp. 335–349.

cent form, it being immaterial whether the gas was prepared electrolytically or chemically. A small amount only of this active gas was present in hot hydrogen gas. The explanation offered by Richards and Behr for the variation in activity of the various kinds of hydrogen gas is that: ordinary hydrogen gas is molecular; occluded hydrogen gas has been dissociated and is therefore atomic without, however, being ionized.

(To be continued.)

Effects of Storage upon the Properties of Coal. S. W. PARR. (Bulletin No. 97, *Engineering Experiment Station*, University of Illinois, May 28, 1917.)—Freshly-mined coal is chemically very active. Certain constituents have a marked affinity for oxygen, with which they enter into combination at ordinary temperatures. While the extent of this reaction depends upon the variety of the coal and the amount of these active constituents, a very important factor is the fineness of division or the sum-total of the superficial areas of the particles and accessibility of oxygen to the mass. There is an increase of "fines" or slack resulting from storage, greater with some coals than with others. This, together with the saturation of the free-burning constituent with oxygen, checks the fire and gives the appearance of a lack of heat value. However, with an increase of draft and a correct understanding of the combustion conditions to be maintained, a most excellent over-all efficiency can be secured, even from coals which have been in storage for long periods.

The actual loss in heat value resulting from storage is small. It is evident that upon mining out the coal from the bed certain volatile constituents are set free. The heat values represented by such exudations are not great. The tendency to absorb oxygen from the air is also a marked characteristic of freshly-mined coal. This is in reality a chemical process, and is accompanied by the generation of a small amount of heat, but these losses, compared with the total heat available in the coal, are insignificant.

Bituminous coal can be stocked without appreciable loss of heat values, provided the temperature is not allowed to rise above 180° F. Any method of storage, to be successful, must either check or prevent the absorption of oxygen to such an extent that the generation of heat shall not proceed faster than the dissipation and loss of heat due to absorption and radiation. Under-water storage prevents loss of heat values and is not accompanied by deterioration in physical properties, such as slacking. The water retained by the coal upon removal is substantially only that held by adhesion and capillarity. Dry storage is safer and more satisfactory if the fine material is screened out at the storage yard and lump only, preferably sized, is stocked.

The most serious part of the problem relates to the matter of spontaneous heating, and probably the least serious phase relates to deterioration and actual loss of heat values. It is certain that at the present time a better understanding of these difficulties has been reached, and there is reason for believing that this better understanding of the fundamental principles involved will lead to some practicable and safe procedure for the stocking of bituminous coal.

Geothermic Steam Generation. ANON. (*Scientific American*, vol. cxvii, No. 17, p. 305, October 27, 1917.)—The remarkable achievement of successfully utilizing underground volcanic heat for the generation of power in the neighborhood of Lardarello, Central Tuscany, Italy, naturally suggests the possibility of applying the same method in other localities. Such utilization of the internal heat of the earth, however, is dependent upon exceptional physical conditions, and it has occurred to an American engineer, Mr. Nathaniel B. Wales, that these conditions could be produced artificially. The increase in temperature of the earth's strata in proportion to its depth shows a mean average for the entire earth surface of one degree Fahrenheit for every 55 feet of depth. There are many regions, however, where this increase in temperature is far exceeded. Hundreds of areas are to be found in the United States where the temperature rises one degree for every 20 or 25 feet of depth. There is a locality near Boisé, Idaho, where three wells driven to only 400 feet yield 800,000 gallons of water daily at a temperature of 170°.

It is Mr. Wales's plan to sink a well-casing wherever the geothermic conditions are favorable until a stratum of high temperature, say 350° to 450° Fahrenheit or higher, is penetrated. Surrounding this shaft, a number of other casings would be sunk. Water would be injected into the heated stratum through the central well-casing, and the head of the water would cause it to percolate through the surrounding strata, from which it would absorb heat and be converted into steam. The steam then would rise through the circle of well-casings surrounding the central water shaft, and could be employed for power or heat. In this way a large zone embracing several acres could be utilized to form the active heating surface, drawing heat through the contiguous rock from an enormous radiant rock contact and allowing an inflow of heat from millions of tons of the earth's mass. The permanence of such an evaporative surface is amply proved by the maintenance of hot artesian wells, which are to be found throughout the world.

There are many areas in this country where borings not over 5000 feet would give the necessary temperature, and others of 1500 feet or less would supply all the heat required. In some places the steam generated might have to be used indirectly because of the earth's salts held in suspension; but no doubt these salts could very profitably be recovered and would add to the value of the installation.

PHYSICS OF THE AIR.*

BY

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CHAPTER XI.

BAROMETRIC FLUCTUATIONS.

THE pressure of the atmosphere undergoes changes that may be classified as seasonal, regional, storm, "ripple," diurnal, and semidiurnal. Most of these have already briefly been referred to, but they deserve further and separate consideration.

Seasonal Pressure Changes.—Since the atmosphere both expands and becomes more humid with increase of temperature, and when cooled contracts and also loses moisture, it follows that the resulting circulation, due to gravity, decreases the mass of air, and therefore its pressure, over places at or near sea level in any warming region and increases it, and its pressure, at similar levels over cooling regions. Hence, in general, the normal reading of the barometer at sea level is greater during winter than summer. It is not much greater, however—perhaps two or three millimetres on the average—since the viscosity of the atmosphere is too small to enable it to maintain any considerable pressure gradient. At places of high elevation the average actual (not reduced) pressure is *less* during winter than summer because of the increased density, during the colder season, of the lower air.

The approximate level at which January and July pressures, say, are equal may be computed as follows:

Let the sea-level pressures differ by 2.5 mm. and let the January temperature of the lower air be 20° C. colder than that of July. The pressure difference represents a stratum of the lower air about 27 metres thick, while the temperature difference is, roughly, 0.075 of the absolute temperature. Hence, under the above conditions, the height h at which the January and July pressures are the same is given approximately by the equation:

$$h = \frac{27 \text{ metres}}{0.075} = 360 \text{ metres.}$$

In addition to this seasonal pressure change over the whole of the northern and southern hemispheres, complicated to some ex-

* Continued from page 117, vol. 185, January, 1918.

tent by local conditions and the shifting of the belts of high pressure, there also are similar but greater pressure changes between the continents (high in winter, low in summer) and oceans (high in summer, low in winter) of each hemisphere itself. This pressure swing between continent and ocean is due to the fact that the summer temperature of the land is much higher and its winter temperature much lower than that of the water.

Regional Pressure Changes.—The great semipermanent lows and highs often shift more or less from their normal positions. These displacements may be in any direction (more frequent in some than in others) and may last for any length of time, from a day or two to a fortnight or even longer. Such pressure changes, whatever their immediate cause, obviously are not seasonal, since they occur at all times of the year. Neither are they of the migratory storm type, though themselves contributing to the genesis and development of storms and of great importance in the control of storm courses.

Storm Pressure Changes.—The progressive travel of cyclones and anticyclones, or, rather, of cyclonic and anti-cyclonic conditions, necessarily implies a regular order of pressure changes, through a range often amounting to 25 mm. or more, at each point along the storm path. This type of change, frequent in extratropical regions at all times of the year, seldom lasts longer than 24 to 36 hours, and averages, perhaps, about 18 hours.

A secondary pressure change, due to the rapid rotation of a tornado or a waterspout, very intense but exceedingly brief—averaging less than one minute—occasionally develops under special conditions.

Perhaps, too, the pulsatory irregularities of the barometer during a thunderstorm should also be included here. Their origin, however, is entirely different.

Barometric "Ripples."—Small pressure changes, amplitude usually 0.1 mm. to 0.3 mm. and period of 5 minutes to 10 minutes, Fig. 54 (the regularly spaced vertical lines along the trace are hour marks), and continuing for hours or even days together, are very common during cold weather. As first demonstrated by Helmholtz,[60] whenever layers of air that differ in density at their

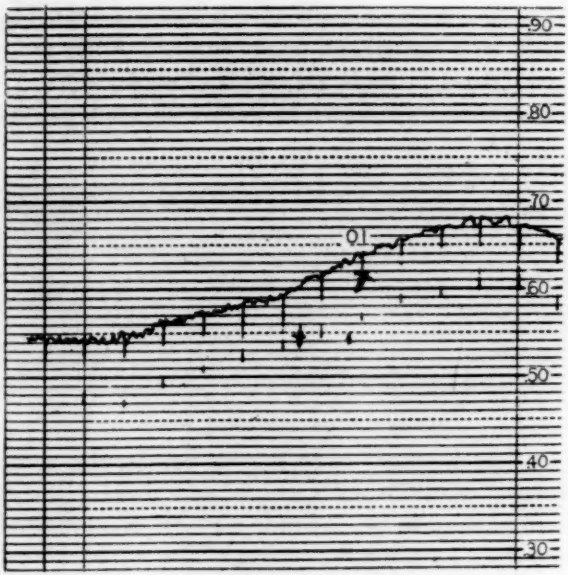
[60] *Sitz. der K. P. Akad. Berlin*, 1889, p. 761; 1890, p. 853. Translated by Cleveland Abbe, "Mechanics of the Earth's Atmosphere," Smithsonian Institution, 1891.

interface flow over each other long billows, analogous to gravity water waves, are produced which conform approximately to the equation,

$$d_1 (u - V)^2 + d_2 (V - v)^2 = \frac{g\lambda (d_2 - d_1)}{2\pi}$$

in which V is the velocity of wave propagation, d_1 and d_2 the densities of the layers whose velocities are u and v, respectively, g the gravity acceleration, and λ the wave-length. If, now, the

FIG. 54.



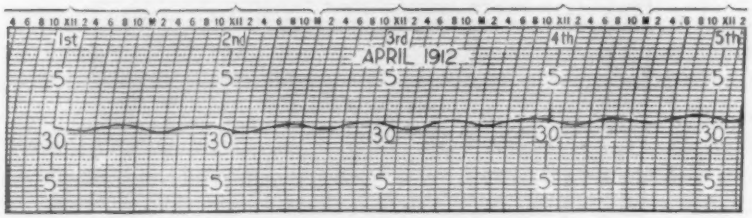
Barometric ripples.

under layer is colder than the upper, as often happens during winter, and rather shallow, 100 metres to 500 metres thick, say, the passage of the air billows, like the passage of waves in shallow water, necessarily produces greater or less corresponding changes in the pressure on the bottom—changes that appear as a series of ripples in the record of a sensitive barograph. Furthermore, such shallow air billows, like shallow water waves, doubtless are turbulent—a condition that accounts, presumably, for the surprisingly rough flying the aviator often experiences during winter at low levels—300 metres and less.

During summer, when air billows rarely form near the surface, though frequently at greater altitudes, especially that of the cirrus cloud, neither barometric ripples nor shallow turbulences of the kind just mentioned often occur. This, doubtless, is because wave disturbances in air as in water do not penetrate far beneath the wave level.

Diurnal and Semidiurnal Pressure Changes.—It has been known now for two and a half centuries that there are more or less regular daily variations in the height of the barometer, culminating in two maxima and two minima during the course of 24 hours. The phenomenon in question is well illustrated by Fig. 55, a direct copy of a barograph trace obtained April 1–5, 1912, on Grand Turk Island, latitude 21° 21′ N., longitude 70° 7′ W. It is further illustrated, and shown to persist through all the seasons,

FIG. 55.



Barogram, Grand Turk Island, West Indies.

by Fig. 56, which gives, from hourly values, the actual average daily pressure curve for each month, and also for the entire year, as observed at Key West, latitude 24° 33′ N., longitude 81° 48′ W., during the 14 years, 1891–1904. The actual values are given in the accompanying table.

Probably the earliest observations of these rhythmical daily changes in the atmospheric pressure were made by Doctor Beal [61] during the years 1664–65, and therefore very soon after the invention, 1643, of the mercurial barometer. Since Beal's discovery the same observation has been made and puzzled over at every station at which pressure records were kept and studied, but without success in finding for it any adequate physical explanation. In speaking of the diurnal and semidiurnal variations of the barometer, Lord Rayleigh [62] says:

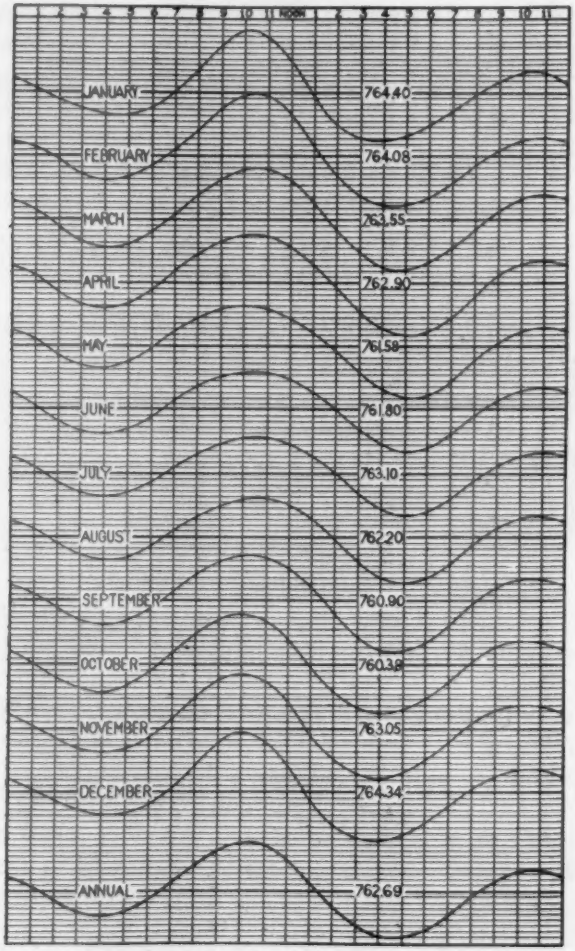
[61] *Phil. Trans.*, 9 (1666), p. 153.
[62] *Phil. Mag.*, 29 (1890), p. 179.

Average Hourly Readings of the Barometer, 1891–1904, at Key West, Latitude 24° 33′ N., Longitude 81° 48′ W.; Elevation. 7 Metres.

75th Meridian time	January	February	March	April	May	June	July	August	September	October	November	December	Year
Average	764.40	764.08	763.55	762.90	761.58	761.80	763.10	762.20	760.90	760.38	763.05	764.34	762.69
1 A.M.	+.07	+.15	+.17	+.15	+.12	+.02	+.12	+.15	+.14	+.02	+.05	+.05	+.10
2 A.M.	−.11	−.05	−.10	−.14	−.14	−.20	−.14	−.10	−.10	−.21	−.16	−.11	−.13
3 A.M.	−.27	−.30	−.38	−.39	−.34	−.38	−.34	−.30	−.35	−.39	−.34	−.31	−.34
4 A.M.	−.37	−.41	−.48	−.45	−.37	−.41	−.39	−.40	−.42	−.46	−.39	−.38	−.41
5 A.M.	−.39	−.38	−.43	−.34	−.29	−.34	−.34	−.35	−.35	−.34	−.36	−.38	−.36
6 A.M.	−.29	−.20	−.20	−.11	−.06	−.13	−.19	−.15	−.15	−.13	−.16	−.26	−.15
7 A.M.	+.02	+.13	+.12	+.25	+.27	+.17	+.10	+.15	+.19	+.20	+.17	+.08	+.15
8 A.M.	+.40	+.46	+.31	×.50	+.50	+.45	+.32	+.34	+.44	+.50	+.52	+.43	+.43
9 A.M.	+.83	+.82	+.74	+.72	+.65	+.58	+.50	+.54	+.67	+.78	+.83	+.84	+.71
10 A.M.	+1.10	+1.05	+.87	+.82	+.70	+.63	+.57	+.66	+.80	+.88	+.96	+1.04	+.83
11 A.M.	+.98	+1.05	+.89	+.82	+.67	+.65	+.62	+.69	+.77	+.78	+.83	+.81	+.81
Noon	+.54	+.71	+.68	+.62	+.55	+.55	+.52	+.56	+.56	+.42	+.45	+.50	+.56
1 P.M.	−.08	+.18	+.23	+.32	+.29	+.30	+.30	+.31	+.24	−.05	−.11	−.16	+.15
2 P.M.	−.57	−.33	−.20	−.06	−.06	+.00	+.05	−.02	−.20	−.46	−.51	−.59	−.26
3 P.M.	−.80	−.68	−.56	−.50	−.44	−.33	−.31	−.40	−.60	−.72	−.77	−.77	−.56
4 P.M.	−.83	−.86	−.84	−.80	−.75	−.59	−.59	−.71	−.86	−.85	−.87	−.84	−.79
5 P.M.	−.73	−.83	−.89	−.90	−.88	−.74	−.72	−.79	−.86	−.77	−.75	−.74	−.79
6 P.M.	−.57	−.71	−.76	−.85	−.85	−.69	−.65	−.71	−.71	−.59	−.54	−.53	−.69
7 P.M.	−.34	−.48	−.50	−.60	−.60	−.41	−.41	−.45	−.42	−.31	−.26	−.26	−.41
8 P.M.	−.01	−.15	−.18	−.21	−.22	−.08	−.11	−.12	−.05	+.07	+.10	+.05	−.08
9 P.M.	+.19	+.10	+.12	+.12	+.04	+.15	+.12	+.15	+.24	+.32	+.30	+.28	+.17
10 P.M.	+.32	+.26	+.36	+.32	+.27	+.33	+.30	+.34	+.39	+.42	+.40	+.38	+.36
11 P.M.	+.32	+.34	+.41	+.37	+.34	+.40	+.35	+.39	+.39	+.40	+.40	+.38	+.38
Midnight	+.22	+.26	+.33	+.30	+.27	+.30	+.30	+.28	+.29	+.25	+.25	+.23	+.27

"The relative magnitude of the latter [semidiurnal variation], as observed at most parts of the earth's surface, is still a mystery, all the attempted explanations being illusory."

FIG. 56.



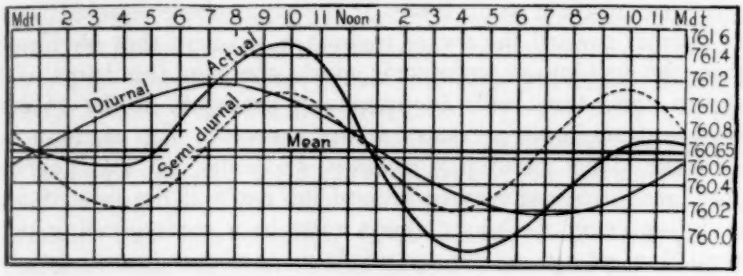
Average daily barometric curves, Key West, Florida.

Obviously the average hourly pressures for a decade or longer at any given place are practically free from storm and other irregular effects, but contain all diurnal and shorter period disturbances

that may exist. On being analyzed these actual data show two well-defined sine curves, a diurnal and a semidiurnal, as illustrated by Fig. 57,[63] each of which requires a special explanation. Higher harmonics of very small amplitude have also been found, but, as neither the diurnal nor the semidiurnal disturbances can have true sine values throughout, it follows that the higher harmonics indicated by this type of analysis may not represent any actual force of the same periodicity.

Diurnal Pressure Changes.—There are two classes of well-defined 24-hour pressure changes. One obtains at places of considerable elevation and is marked by a barometric maximum during the warmest hours and minimum during the coldest. The

FIG. 57.



Average daily barometric curve and its components, Washington, D. C.
(After W. J. Bennett.)

other applies to low, especially sea level, stations and is the reverse of the above, the maximum occurring during the coldest hours and the minimum during the warmest.

The first class of changes just mentioned, the one that concerns elevated stations, is due essentially to volume expansion and contraction of the atmosphere caused by heating and cooling respectively. Thus the lower atmosphere over that side of the earth which is exposed to insolation becomes more or less heated, and therefore, because of the resulting expansion, its centre of mass is correspondingly raised. Conversely, during the night the atmosphere cools and contracts and the centre of mass is proportionately lowered. Hence, so far as this effect alone is concerned, a mountain station, 1000 metres, say, above sea level, will have

[63] Bennett, *Monthly Weather Review*, 34 (1906), p. 528.

the greatest mass of air above it when the atmosphere below is warmest or most expanded, and the least when the lower atmosphere is coldest or most contracted—that is to say, this effect tends to produce, at such stations, barometric maxima during afternoons and minima about dawn.

There is, however, another effect resulting from the volume expansion and contraction of the atmosphere to consider; namely, its lateral flow. To this, mainly, is due that daily barometric swing at sea level, as shown by harmonic analysis, the early evening minimum and the early morning maximum, that is the reverse of the high-level oscillation.

The expansion and consequent vertical rise of the air on the warming side of the earth, together with the simultaneous contraction and fall of the atmosphere on the cooling side, establishes a pressure gradient at *all* levels of the atmosphere directed from the warmer toward the cooler regions, a gradient that obviously causes the well-known heliotropic wind—the wind that turns with the sun—and thus leads to maximum pressures at the coldest places and minimum pressures at the warmest. But as these regions are along meridians, roughly, 10 hours, or 150 degrees apart, and perpetually move around the earth at the rate of one revolution every 24 hours, there must be a corresponding perpetual flow of air, or change of flow, as above described, in a ceaseless effort to establish an equilibrium which, since the disturbance is continuous, can never be attained.

Semidiurnal Pressure Changes.—Both the actual barometric records and their harmonic analyses show conspicuous 12-hour cyclic changes that culminate in maxima and minima at approximately 10 o'clock, A.M. and P.M., and 4 o'clock, also both A.M. and P.M., respectively—the exact hour in each case depending somewhat upon season, elevation, and, presumably, weather conditions.

Some of the observed facts in regard to this 12-hour cyclic change of pressure are:[64]

(*a*) The amplitude is greatest in the tropics and decreases to-

[64] Angot, "Étude sur la marche diurne du baromètre," *Annales du Bureau Central Météorol.*, 1887.

Hann, "Untersuchungen über die tägliche Oscillation des Barometers" *Denkschriften der Wiener Akademie*, Bd. 55, 1889.

Hann, *Meteorol Zeit.*, **15** (1898), 361.

ward the poles, approximately as the square of the cosine of the latitude.

(*b*) The amplitude is everywhere greatest on equinoxes and everywhere least on solstices.

(*c*) The amplitude is greater at perihelion than at aphelion.

(*d*) The amplitude is greater by day than by night.

(*e*) The amplitude is greatest on clear days and least on cloudy.

(*f*) The day amplitude is greater over land than over water.

(*g*) The night amplitude is greater over oceans than over continents.

(*h*) Over the tropical Pacific Ocean the forenoon barometric maximum is about 1 mm. above and the afternoon minimum 1 mm. below the general average pressure.

Obviously, other things being equal, both the daily change in temperature and the resulting change in convection are greater in the tropics than elsewhere; greater at perihelion than at aphelion; greater during clear weather than cloudy; greater over land than over water; and greatest when the time of heating and the time of cooling (day and night) are equal, and least when these are most unequal or at the times of solstice. Hence all the above facts of observation strongly favor, if they do not compel, the conclusion that the daily cyclic pressure changes are somehow results of daily temperature changes. There are, however, a number of other causes of slight pressure changes,[65] but apparently only the following have any appreciable value:

1. *Horizontal flow of the atmosphere from the regions where it is most expanded toward those where it is most contracted.*

The exact hour at which the atmosphere is warmest and most expanded depends upon a variety of circumstances, but on the average it is approximately at 4 o'clock in the afternoon. Hence, in general, at about this time the amount of air overhead, counting from sea level, should be least, and therefore at this hour a sea-level barometer should have its lowest reading. On the other hand, lowest temperatures and maximum contractions obtain soon after dawn, or shortly before 6 A.M. throughout the year near the equator, and everywhere at the time of equinox.

The 24-hour swing of the barometer, therefore, does not ap-

[65] Humphreys, *Bul. Mt. Weather Obsy.*, 5 (1912), p. 132.

pear to be of even period, but rather of intervals that are to each other, roughly, as 5 to 7. To be sure, the barometer is lower at 6 o'clock in the afternoon than at the same hour of the morning, and hence one may assume an even period 24-hour swing, with a morning 6 o'clock maximum and evening 6 o'clock minimum, and partially correct this regular curve (the correction is never perfect) by the superposition of one or more additional sine curves of convenient periods. But this approximation to the true curve does not prove the existence of actual forces with the periods assumed.

It appears, then, that the physical causes of the 24-hour component of the diurnal pressure changes are such as to give a morning maximum at about 6 o'clock and an afternoon minimum at about 4 o'clock. The above causes of pressure change, however, do not account for either of the 10 o'clock maxima.

2. *Interference by vertical convection with free horizontal flow.*

It was long ago suggested by Abbe [66] that convectional interference is the principal cause of the forenoon maximum pressure, which indeed it probably is, as the following consideration shows:

Let the mass m of air be near the ground and have the horizontal velocity v, and let the larger mass M be at a higher elevation and have the greater velocity V in the same direction. If now these two masses should mingle in such manner as to be free from all disturbance, except their own mutual interference, the resulting final velocity, U, in the same direction, would be given by the equation—

$$U = \frac{mv + MV}{m + M}$$

and there obviously would be no check in the total flow—no damming up and consequent increase of pressure. But this simple mixing of the two masses is by no means all that happens in the case of vertical convection. The rise of the mass m is simultaneously accompanied by an equivalent descent of air from a higher level, which in turn loses velocity, directly or indirectly, by surface friction. If the falling mass is also m, and if its velocity is reduced by friction to v, then from a single interchange, due to vertical convection, the total momentum becomes—

$$2\,mv + (M - m)\,V$$

[66] "Preparatory Studies" (1890), pp. 8 and 56.

and the total flow is reduced by the amount

$$m\,(V-v)$$

But as this is for a single interchange, it is obvious that the more active vertical convection becomes, the greater will be its interference with the flow of the atmosphere, the more the winds will be dammed up, and the higher the barometric pressure. As convection increases, reaches a maximum, and then decreases, so, too, will the resulting interference go through the same changes.

Now the general movement of the atmosphere is from east to west within the tropics and from west to east at higher latitudes. Therefore in either case such damming up of the air as vertical convection may produce will be essentially along meridians, and thus a function of the time of day. But, in general, convection increases most rapidly during the forenoon, say 8 to 9 o'clock, is most active at 10 to 11 o'clock, and reaches its greatest elevation about 4 o'clock in the afternoon. Hence the damming up of the atmosphere, due to vertical convection, and the resulting increase of barometric pressure must increase most rapidly during the forenoon, and come to a maximum about 10 o'clock. After this the convectional interference decreases, while at the same time the amount of air in a vertical column of fixed cross-section decreases as a result of expansion and overflow, until at about 4 o'clock in the afternoon the barometric pressure, as already explained, has reached a minimum.

To form some idea of the magnitude of the barometric change due to convectional turbulence, consider the atmosphere between two parallels of latitude near the equator. This limited quantity may be regarded as a stream flowing around the earth, having its minimum velocity and maximum depth where convectional interference is greatest, and maximum velocity with minimum depth where convection is absent. And since the linear velocity of a point on the equator is approximately 28 kilometres per minute, while during the forenoon the rate of increase of the barometric pressure at the same place is, roughly, 0.2 mm. per hour, it follows that a damming up, or check in the flow, of the given stream at the rate of 0.44 kilometre per hour would be sufficient of itself to account for the observed rise in the barometer. But if the average velocity of the wind, or flow of the stream in question, is 10 metres per second, which it may well be, the rate of decrease in velocity requisite for the given rate of pressure in-

crease could be produced by having only 1 part in 80 of the whole superincumbent atmosphere brought to rest per hour, or the equivalent thereof, an amount that perhaps is reasonable. At any rate, the assumed velocity decrease is of the same order of magnitude as that observed to take place during, and as the result of, diurnal convection.

Summing up the effects of all the above causes of barometric changes, it appears:

(*a*) That the afternoon minimum is caused essentially by overflow from the region where the atmosphere is warmest, or better, perhaps, from the meridian along which the temperature increase has been greatest, toward that meridian along which there has been the greatest decrease in temperature.

(*b*) That vertical convection interferes with the free horizontal flow of the atmosphere and to that extent dams it up and correspondingly increases the barometric pressure; also, that the time of this interference agrees with the forenoon changes of the barometer, and that its magnitude is of about the proper order to account for the forenoon barometric maximum.

The afternoon barometric minimum and the forenoon maximum, therefore, are to be regarded as effects of temperature increase; the minimum as due to expansion and consequent overflow; the maximum as caused by vertical convection and consequent interference with the free circulation of the atmosphere.

The forced afternoon minimum would occur in an otherwise stagnant atmosphere, and substantially as at present; but not so with the forced forenoon maximum, since the interference or damming effect depends upon a flow or circulation of the atmosphere, parallel roughly to the equator.

It remains now to account for the night 10 o'clock maximum and 4 o'clock minimum.

3. *Natural or free vibration of the atmosphere as a whole.*

This subject has been discussed by several mathematical physicists of great eminence. The latest and most complete of these discussions, and the one to which those interested in this phase of the barometric problem are especially referred, is by Lamb,[67] who concludes:

"Without pressing too far conclusions based on the hypothesis

[67] *Proc. Roy. Soc.*, A. **84** (1911), p. 551.

of an atmosphere uniform over the earth, and approximately in convective equilibrium, we may, I think, at least assert the existence of a free oscillation of the earth's atmosphere, of 'semidiurnal' type, with a period not very different from, but probably somewhat less than, 12 mean solar hours."

Hence any cause of pressure change, having a semidiurnal period or approximately so, would, if of sufficient magnitude and proper phase, account for the 12-hour barometric curve. Such a cause, many think, may be found in the irregular daily march of temperature, since the curve expressing this march is more or less approximately resolvable into a diurnal and a semidurnal sine curve. But the resolution is not perfect and, besides, there is no obvious cause for a temperature increase by night, and hence the reality of the semidurnal component in the temperature curve is equally doubtful.

All that is needed, apparently, to give the semidiurnal pressure curve is a pressure impulse of the same period, 12 hours, as that of the free vibration of the atmosphere as a whole. And this is furnished by the forced forenoon barometric maximum, followed six hours later at the same place by the forced afternoon barometric minimum. In other words, taken altogether, the forenoon and afternoon forced disturbances appear to occur with the proper time interval necessary to set up and maintain the 12-hour free vibrations of the atmosphere.

The course of events at each locality appears to be substantially as follows:

1. A forced forenoon compression of the atmosphere, followed by its equally forced afternoon expansion, the two together forming one complete barometric wave, with a 10 o'clock maximum and a 4 o'clock minimum, in harmony with the free vibration of the entire atmospheric shell.

2. Nondisturbance through the night or during the time of a single free vibration.

3. Repetition the following day of the forced disturbances in synchronism with, and therefore at such time as to reënforce, the free vibrations.

The series of disturbances is continuous, forced by day and free by night, but the resulting amplitudes of the barometric changes are limited, through friction and through the absence of perfect synchronism, to comparatively small values. Each point

upon the atmospheric shell receives at every alternate swing a forced impulse in phase with the free vibration, and therefore at such time and in such manner as indefinitely to maintain the vibrations of the atmosphere as a whole.

The forenoon maximum and the afternoon minimum are primary disturbances equally forced but in different ways by the daily increase of temperature, while the evening maximum and the morning minimum are secondary disturbances caused by the joint action of the forced primaries through the 12-hour free vibration of the atmosphere. In short, the semidiurnal swing of the barometer is a result of merely fortuitous circumstances—of the fact that the mass of the atmosphere happens to be such that the period of its free vibration is approximately just one-half that of the earth's rotation.

(To be continued.)

Power Transmission Through Separating Diaphragms. ANON. (*Electrical World*, vol. 70, No. 25, p. 1188, December 22, 1917.)—The invention of Benjamin Graemiger, of Zurich, Switzerland, patent No. 1,233,569, relates to apparatus for driving machines by means of purely magnetic forces, such that the driving and driven members are separated from each other in a gas-tight manner without the provision of a stuffing box by a partition or wall. Accordingly metal alloy of great strength and which is a very bad electrical conductor is employed for the separating partition between the driving end and driven members. The power-driven machine inclosed in a casing is driven, for instance, from the exterior without involving the use of a stuffing box by inclosing the rotor of an electromotor of any suitable construction coupled to the shaft of the machine in the casing and by separating the driving member—that is to say, the stator of the motor—in a gas-tight manner from the rotor by a wall or partition forming a part of the casing.

On the shaft driven by a prime mover is keyed the driving member, consisting of two disks between which is arranged the winding required for excitation purposes. The two disks have cylindrical polar surfaces arranged facing each other and formed with projections. The driven member is keyed on a shaft of the machine to be driven and consists of a bell-shaped disk, the cylindrical portion of which extends between the two polar surfaces of the driving member and is also formed with projections on the inside and the outside. The separating partition arranged between the two members is in the form of a ring of U-section and is connected in a gas-tight manner to the parts of the casing. The action of the drive is due to the magnetic flux lines generated by the energizing winding.

OUTLINE OF COLLOID CHEMISTRY.—III.*

BY

WILDER D. BANCROFT.

PREPARATION OF COLLOIDAL SOLUTIONS.

Types of Precipitates.

IT has been shown that sufficiently finely divided particles will be kept in suspension in a liquid indefinitely by the Brownian movements, provided coalescence and the resulting agglomeration are prevented. A stable colloidal solution will therefore consist of very fine particles kept from agglomerating by a protecting film[1] of some sort, electrification being equivalent to a film.[2] Small particles[3] may be obtained either by condensation from vapor or solution (usually called precipitation) or by disintegration of larger masses. The disintegration is often called peptization, especially when done chemically, as opposed to mechanical or electrical disintegration. It seems desirable to distinguish eight types of precipitates: crystalline; colloidal or non-settling; flocculent; curdy; sandy; gelatinous; jelly-like; fluid. A crystalline precipitate is one that is distinctly crystalline and settles rapidly, as when KOH is neutralized by H_2SO_4 or when moderately concentrated solutions of lead nitrate and potassium chromate are mixed. A non-settling precipitate may be anhydrous or hydrous; there is little or no agglomeration. A typical case is the precipitation of lead chromate from very dilute solutions of lead nitrate and potassium chromate. A flocculent precipitate is obtained when a non-settling, non-gelatinous precipitate agglomerates to a bulky mass. It is easy to obtain a flocculent precipitate of silver chloride from suitable solutions of silver nitrate and potassium chloride. Haber and Oordt[4] call the precipitate of beryllium hydroxide flocculent; but I am not certain whether they are limiting the term sufficiently sharply. A curdy precipitate is obtained

* Based on a paper presented at a meeting of the Section of Physics and Chemistry, held Thursday, January 11, 1917.

[1] Cf. Höber: *Physikalische Chemie der Zelle und der Gewebe*, 233. (1914).

[2] Cf. Hardy: *Proc. Roy. Soc.*, **86 A**, 601 (1912).

[3] Freundlich: "*Kapillarchemie*," 527 (1909).

[4] *Zeit. anorg. Chem.*, 38, 377 (1904).

when a flocculent precipitate agglomerates to a fairly dense mass. The typical case is, of course, the precipitation of caseine by acids, but a similar precipitate can be obtained with $AgNO_3$ and HCl. There is no sharp dividing line between a flocculent and a curdy precipitate. A sandy precipitate is obtained when a flocculent or a curdy precipitate agglomerates to a dense mass. The alumina obtained from hot sodium aluminate in the Bayer process is a sandy precipitate.[5] A granular or sandy alumina is said to be precipitated by ammonia[6] at 66°. A gelatinous precipitate is always hydrous and viscous; it involves agglomeration to a bulky form. Hydrous alumina and hydrous ferric oxide, when precipitated cold, are typical gelatinous precipitates. When a salt is precipitated from very concentrated solutions we apparently always get a gelatinous precipitate. Thus gelatinous barium sulphate is obtained by mixing concentrated solutions of barium sulphocyanate and manganous sulphate,[7] and gelatinous calcium carbonate by mixing concentrated solutions of calcium chloride and sodium carbonate. The difference between a gelatinous precipitate and a jelly is that the liquid phase is visible as such in the case of the gelatinous precipitate and is not in the case of the jelly. A jelly is always hydrous, viscous, and bulky; it may consist of a number of coalescing drops or rods, in which case both phases are continuous; or it may consist of coalescing films, in which case we have a honeycomb structure, with water as the internal phase. A typical jelly can be obtained with sodium silicate and hydrochloric acid. A fluid precipitate is one which is too mobile to be classed as a gelatinous precipitate. Sodium phenolate or sodium oleate with an excess of HCl gives a fluid precipitate.

The mean mass of the crystals in a crystalline precipitate is given by the total weight of the precipitate divided by the number of crystals. Experimentally we find that the number of nuclei increases less rapidly than the concentration at first and more rapidly later. When very dilute solutions are mixed, the number of nuclei is so large relatively to the weight of the precipitate that the particles themselves are very small. With increasing concentration we get increasing size of crystals for a

[5] Russ: *Zeit. anorg. Chem.*, **41**, 216 (1904).
[6] Taylor *Chem. News*, **103**, 169 (1911).
[7] Von Weimarn: "Gründzüge der Dispersoidchemie," 67 (1911).

while and then decreasing size, because the number of nuclei then increases more rapidly than the concentration. At very high concentrations a gelatinous precipitate is always obtained, as has been pointed out. It is possible that we have here the appearance of a viscous and instable second liquid layer; but this has not yet been proved. At the Urbana meeting of the American Chemical Society, Clowes pointed out that a jelly is formed when a hydrous, viscous phase separates slowly in presence of a substance which tends to keep it dispersed.[8] To obtain large crystals one must have a solution so slightly saturated that no nuclei form spontaneously and that no branched crystals form in presence of a single crystal.[9] Von Weimarn[10] cites the case of a spring in which crystals of barium sulphate had grown 5 cm. long. It is easier to avoid excessive supersaturation when the substance is more soluble. Thus one can get crystals of silver chloride without trouble by dissolving the salt in ammonia.[11] The effect of other substances in the solution depends on their effect on the supersaturation and on whether they are adsorbed by the precipitate. This has been discussed fully for the case of barium sulphate by Weiser.[12] The question has been raised whether the finest precipitates are crystalline or amorphous. Von Weimarn[13] considers them all crystalline; but he considers that liquids and gases are crystalline, which throws him out of court, because he is not using the word in the same sense as other people. A supercooled liquid like glass is amorphous in the ordinary sense of the term. Whether a precipitate is amorphous or not is therefore a question whether it is a supercooled liquid or not. Von Weimarn is undoubtedly right in saying that many precipitates are really crystalline, though they are classed as amorphous; but there is no question that there are amorphous precipitates.

At higher temperatures precipitates are less hydrous and tend to be more coarsely crystalline. When barium sulphate is precipitated hot it does not run through the filter so readily as when precipitated cold. Other conditions being the same, a non-set-

[8] Cf. Hardy: *Jour. Physiology*, **24**, 167 (1899); *Proc. Roy. Soc.*, **66**, 95 (1900); **87 A**, 29 (1912).

[9] Cf. Hopkins: *Am. Chem. Jour.*, **25**, 413 (1907).

[10] "Grundzüge der Dispersoidchemie," 55 (1911).

[11] Reinders: *Zeit. phys. Chem.*, **77**, 696 (1911).

[12] *Jour. Phys. Chem.*, **21**, 314 (1917).

[13] *Zeit. Kolloidchemie*, **3**, 166 (1908).

tling precipitate of silver[14] is obtained by reduction with hydrazine at 16° and pulverulent silver by reduction at 80° to 90°.

Theory of Peptization.

We find experimentally that certain solutions will peptize or disintegrate certain precipitates so that we get colloidal solutions. This is always the result of adsorption. Theoretically there are three possibilities. If an adsorbed film has a low surface tension on the water side and a high one on the other side, it will tend to scrunch up and to peptize the solid as internal phase. If the reverse is the case, the solid will tend to form the external phase. If the two surface tensions are practically equal, neither will prevail. Some adsorbed substances seem to have practically no peptizing action;[15] but these cases should be studied again in the light of what we now know about colloid chemistry. If we adopt Freundlich's view that adsorption always lowers the surface tension, a theory of peptization follows at once.[16] We may have peptization by a liquid, by a non-electrolyte, by an adsorbed ion, by a salt, or by a peptized colloid. When a liquid is adsorbed by a solid, it will tend to peptize it and in some cases will do so. Water peptizes tannin, amyl acetate peptizes pyroxylin, and fused baths peptize metals. At higher temperatures the peptizing action increases, and we may get glass peptized by water[17] or vulcanized rubber by various organic liquids.[18] Gelatine is not peptized by cold water, but is by warm water. A concentrated solution of sugar in water will prevent the precipitation of calcium silicate, silver chromate, and silver chloride; also of lime and the hydrous oxides of copper and iron. There are a number of cases where mixed solvents will peptize a solid much better than either alone: cellulose nitrate in ether and alcohol, caseine in pyridine and water,[19] and probably cinchonine in chloroform and alcohol,[20] and also phloretine in ether and water.[21] The theory of this has

[14] Gutbier: *Zeit. Kolloidchemie*, **4**, 308 (1909).
[15] Doyle: *Jour. Phys. Chem.*, **17**, 390 (1913).
[16] Bancroft: *Jour. Phys. Chem.*, **20**, 85 (1916).
[17] Barus: *Am. Jour. Sci.* (3), **38**, 408 (1889); **41**, 110 (1891); (4) **6**, 270 (1898); **7**, 1 (1899; *Phil. Mag.* (5), **47**, 104, 461 (1899).
[18] Barus: *Am. Jour. Sci.* (3), **42**, 359 (1891).
[19] Levites: *Zeit. Kolloidchemie*, **8**, 4 (1911).
[20] Oudemanns: *Jour. Chem. Soc.*, **26**, 533 (1873).
[21] Schiff: *Zeit. Phys. Chem.*, **23**, 355 (1897).

not been worked out. Cellulose nitrate swells in alcohol and not in ether;[22] but it is not known whether this is universal or whether alcohol peptizes cellulose nitrate at higher temperatures. Zein is also peptized in mixed solvents.[23]

Freshly precipitated silver chloride is peptized by $AgNO_3$ or KBr, the silver and the bromine ions being adsorbed strongly. Many oxides are peptized by their chlorides or nitrates, forming so-called basic salts. Sulphides are peptized by hydrogen sulphide.[24] Gelatine is liquefied or peptized by a potassium iodide solution. There are no cases where it has been shown conclusively that peptization is due chiefly to adsorption of unadsorbed salt, but undoubtedly such instances will be found. Water-peptizable colloids like gelatine, dextrine, soap, or saponin will peptize many precipitates, and they are often called protecting colloids, because they prevent the agglomeration and settling of finely divided precipitates. Caseine is not peptized by water, but is peptized by acids and alkalies, and then acts as a protecting colloid. Hydrous chromic oxide is peptized by caustic potash and can then prevent the precipitation of hydrous ferric oxide, etc. If too much ferric oxide is present, all the chromic oxide is carried down by it.[25]

Since a colloidal solution is one in which we have a finely divided phase which is kept from coalescing in some way, it is clear that we may theoretically have as many colloidal alumina solutions as we please, varying all the way from anhydrous alumina (Al_2O_3) up to the most highly hydrous form that can be obtained. As a matter of fact, people have generally been satisfied with distinguishing only two sets of solutions, which they have called solutions of alumina and metalumina, stannic and metastannic acids, etc.[26] The theory of mechanical and electrical disintegration or peptization is so simple that it does not need to be discussed here, and it will be referred to when discussing the details of methods of preparing colloidal solutions. These methods are grouped under two main heads, the condensation

[22] Private communication from Professor Chamot.

[23] Galeotto and Giampalmo: *Zeit. Kolloidchemie*, 3, 118 (1908).

[24] Young: *Jour. Phys. Chem.*, **21**, 1, 14 (1917).

[25] Northcote and Church: *Jour. Chem. Soc.*, 6, 54 (1854); Nagel: *Jour. Phys. Chem.*, **19**, 331 (1915).

[26] Hautzsch: *Zeit. anorg. Chem.*, **30**, 338 (1902); Bancroft: *Jour. Phys. Chem.*, **19**, 232 (1915).

methods and the dispersion methods. The condensation methods are to be discussed first.

Condensation Methods.

In condensation methods we must have strong adsorption (including protecting colloids), or we must keep down the concentration of agglomerating agents either by choice of reagents or by dilution. A few instances will be given of the preparation of colloidal solutions in the presence of a strongly adsorbed substance. Colloidal palladium may be obtained by reduction with hydrazine in presence of gum arabic.[28] Colloidal solutions of silver chloride, silver bromide, or Prussian blue may be obtained by precipitation in presence of gelatine.[29] Sulphide solutions may be stabilized by gum arabic[30] or by sodium sulphide, but not by ammonium sulphide.[31] Silver chromate, hydrous copper oxide,[32] and hydrous ferric oxide may be obtained colloidal in presence of sugar.[33] Invert sugar holds up about seven times as much iron as cane sugar. Glycerin also enables us to make a colloidal solution of ferric oxide.[34] Gengou[35] prepared colloidal alumina and barium sulphate in presence of sodium citrate, and Schiaparelli[36] held up lead sulphide with saponin. A solution obtained by adding sulphuric acid to barium arabinate was milky after standing four years.[37] Cadmium sulphide can be obtained colloidal in presence of caseine,[38] and so can copper oxide,[39] while mercurous chloride can be held up by albumin.[40] All the metals and many other substances can be kept in colloidal solution by sodium protalbinate and lysalbinate, which are salts of somewhat

[27] Svedberg: "Die Methoden zur Herstellung kolloider Lösungen anorganischer Stoffe."
[28] Svedberg, 105.
[29] Svedberg, 323.
[30] Lefort and Thibault: *Jour. Chem. Soc.*, **42**, 1322 (1882).
[31] Haussmann: *Zeit. anorg. Chem.*, **40**, 121 (1904).
[32] Svedberg, 224, 304.
[33] Riffard: *Jour. Chem. Soc.*, **27**, 292 (1874).
[34] Grimaux: *Ibid.*, **46**, 96 (1884).
[35] *Zeit. Kolloidchemie*, **9**, 88 (1911).
[36] *Jour. Chem. Soc.*, **46**, 332 (1884).
[37] *Ibid.*, **30**, 538 (1876).
[38] Svedberg, 325.
[39] Ritthausen: *Jour. Prakt. Chem.* (2), **5**, 215 (1873); **7**, 361 (1874).
[40] Svedberg, 325.

hypothetical acids obtained by saponification of albumin.[41] It is an open question whether they are any more effective than gelatine. Colloidal solutions of silver in organic solvents can be obtained with wool-fat as protecting colloid.[42] Carey Lea prepared colloidal silver of various colors by reduction of a silver salt with ferrous citrate or tartrate.[43] Both red and blue copper solutions have been obtained in presence of lysalbinates.[44] Colloidal gold and silver can be kept from coagulating by means of starch.[45] Mercury and bismuth may be kept up by stannic oxide[46] and gold by ceria,[47] while sodium sulphate keeps up sulphur in strongly acid solution and potassium sulphate precipitates it.[48] Acheson aquadag is kept in colloidal solution by tannin and iron oxide.[49]

In a number of other cases the agglomerating agent is kept low either by selection of the reaction or by dilution. Since electrolytes are very effective in producing precipitation in many cases, this usually means keeping the concentration of electrolytes very low. It may make matters clearer to classify the methods according to the type of reaction involved.

1. *Reduction without Electrolysis.*—At 50° hydrogen gas reacts slowly with silver oxide in presence of water, the dissolved silver oxide being the substance which reacts. The reaction is $Ag_2O + H_2 = 2Ag + H_2O$, so the silver is formed in the absence of electrolytes and tends to come down colloidal, though some does precipitate as a mirror.[50] From dilute solutions of gold salts, colloidal gold can be obtained by reduction with carbon monoxide, sulphur dioxide, formaldehyde, pinene, alcohol, hydrazine, and phenyl hydrazine.[51] In these cases the concentration of electrolytes is kept low by dilution. On the other hand, colloidal copper can be obtained by the action of alcohol on anhy-

[41] Svedberg, 125, 295, 327.

[42] Amberger: *Zeit. Kolloidchemie*, 11, 99 (1912).

[43] Svedberg, 211.

[44] Svedberg, 166, 170.

[45] Gutbier and Weingärtner: *Kolloidchemische Beihefte*, 5, 211, 244 (1913).

[46] Svedberg, 204.

[47] Schottländer: *Jour. Chem. Soc.*, 68 ii, 318 (1895).

[48] Svedberg, 249; Cf. Oden: *Zeit. Kolloidchemie*, 8, 186 (1911).

[49] Cf. Doyle: *Jour. Phys. Chem.*, 17, 390 (1913).

[50] Svedberg, 38.

[51] Svedberg, 60–71, 101, 112.

drous copper sulphate and concentrated sulphuric acid,[52] a reaction which cannot be classified without further study. Colloidal gold can also be obtained by reduction by means of *Aspergillus oryzæ*.[53] The effect of concentration has been studied by Liversidge.[54] Colloidal metals may also be obtained by reduction in flames.[55]

2. *Reduction with Electrolysis.*—When very dilute solutions of gold, silver, and mercury salts are electrolyzed, some of the metal comes out in colloidal form.[56] Billitzer[57] obtained colloidal solutions in a similar way with salts of the less noble metals, but it is probable that the dispersed phase consisted of oxide and not of metal.[58] Lecoq[59] has prepared colloidal arsenic electrolytically, and Sansonoff[60] colloidal UO_2, the latter being stabilized by uranyl chloride.

3. *Oxidation.*—Colloidal sulphur can be obtained from the reaction[61] between H_2S and SO_2, which involves no high concentration of electrolyte. In presence of gelatine as stabilizer colloidal sulphur[62] can be obtained by oxidation of H_2S. Wöhler and Witzmann[63] have prepared iridium dioxide as a violet or blue solution. Bredig and Marek[64] have obtained colloidal manganese dioxide by the action of hydrogen peroxide on permanganate. When aurous chloride breaks down into auric chloride and gold, the latter can be obtained colloidal under suitable conditions.[65]

4. *Hydrolysis.*—Water will hydrolyze any salt until the product of concentrations of the hydroxyl and hydrogen ions reaches a value of about 10^{-14}. If the base is very sparingly soluble, the hydrolysis will run farther. Equilibrium will be reached more

[52] Rasenfosse: *Jour. Soc. Chem. Ind.*, **30**, 133 (1911).
[53] Svedberg, 199.
[54] *Jour. Chem. Soc.*, **60**, 401 (1891).
[55] Donau: *Zeit. Kolloidchemie*, **16**, 81 (1915).
[56] Svedberg, 206.
[57] *Ber. deutsch. chem. Ges.*, **35**, 1929 (1902).
[58] Haber: *Zeit. Elektrochemie*, **8**, 551 (1902).
[59] *Comptes rendus*, **150**, 700 (1910).
[60] *Zeit. Kolloidchemie*, **8**, 96 (1911).
[61] Svedberg, 243.
[62] Himmelbaur: *Zeit. Kolloidchemie*, **4**, 307 (1909).
[63] *Zeit. anorg. Chem.*, **57**, 328 (1908).
[64] *Van Bemmelen Gedenkboek*, 342 (1910).
[65] Vanino and Roessler: *Zeit. Kolloidchemie*, **6**, 289 (1910).

rapidly if the solution is heated. If a dilute solution of ferric chloride is boiled for a few minutes and then cooled, it will not be blackened by hydrogen sulphide[66] and it will not form Prussian blue with potassium ferrocyanide.[67] On the other hand, addition of sodium sulphate or of sulphuric acid will cause a precipitation of hydrous ferric oxide. Colloidal solutions of the hydrous oxide can be obtained by hydrolysis of the acetates, the nitrates, or the chlorides, but not in general by the hydrolysis of sulphates, because sulphuric acid precipitates the colloidal solutions more readily than hydrochloric, nitric, or acetic acid. The so-called chrom-sulphuric acids are apparently special cases of colloidal solutions due to hydrolysis in sulphate solutions.[68] Colloidal solutions can also be obtained by hydrolysis of a few compounds which are not electrolytes,[69] such as silicon sulphide, ferric ethylate, and copper succinimide.

5. *Metathetical Reactions.*—When hydrogen sulphide acts on arsenious oxide, arsenious sulphide is formed practically in the absence of electrolytes, $As_2O_3 + 3H_2S = As_2S_3 + 3H_2O$. This colloidal solution can be made of the very high concentration of 3 g. As_2S_3 per 5 g. water.[70] The reaction between mercuric cyanide and hydrogen sulphide gives prussic acid in solution; but this is a very weak acid and has but slight precipitating power.[71] Colloidal sulphides can also be obtained with salts of strong acids by working in sufficiently dilute solutions.[72] In some cases sodium chloride has relatively little precipitating power, and it is therefore possible to prepare colloidal solutions of silicic acid from sodium silicate, of the so-called stannic and metastannic acids from stannic chloride and sodium stannate respectively;[73] and of tungstic acid from sodium tungstate. The tungstic acid solution can be concentrated until it contains 80 per cent. tungstic acid and has a density of over 3.2, so that glass will float in it.[74]

[66] Wright: *Jour. Chem. Soc.*, **43**, 156 (1883).

[67] Svedberg, 260.

[68] Denham: *Zeit. anorg. Chem.*, **57**, 378 (1908); Strong: *Comptes rendus*, **150**, 1172 (1910).

[69] Svedberg, 276.

[70] Svedberg, 297.

[71] Svedberg, 302.

[72] Winssinger: *Jour. Chem. Soc.*, **54**, 911 (1888).

[73] Svedberg, 303.

[74] Müller: *Van Bemmelen Gedenkboek*, 416 (1910).

If M/20 $AgNO_3$ is mixed with M/20 KCl, KBr, or KI, so that there is a slight excess of one or the other solution,[75] more or less of the silver halide stays in suspension, being charged positively in the one case, owing to adsorption of silver ion, and charged negatively in the other case, owing to adsorption of halide ion. A salt which is readily soluble in water can be obtained in a colloidal state by working in a solvent in which the salt is practically insoluble and therefore precipitates in an extremely finely divided state.[76] Thus colloidal sodium chloride can be obtained by the interaction of sodium malonic ester and chloracetic ester in ligroin.[77]

6. *Decomposition by Light.*—Colloidal solutions can be obtained when substances are precipitated by the action of light. Svedberg[78] has studied the action of light on gold solutions, and Wigand[79] the behavior of sulphur solutions. There are also several other interesting papers along similar lines.[80]

Dispersion Methods.

1. *Removal of Agglomerating Agent.*—If a precipitate has settled from a colloidal solution owing to the addition of too much of an agglomerating agent, the precipitate may go back into apparent solution if the excess of agglomerating agent is washed out. No colloidal solution will be obtained if it is impossible to wash out the coagulating agent or if the agglomeration has gone too far.[81] If a silver halide precipitate is washed on a filter at once, the silver salt is apt to run through the filter when the excess of potassium salt has been removed and there is present only the amount which would have kept the silver halide in suspension originally. When the rare earth nitrates are precipitated by ammonia and then washed, they are liable to stay suspended in

[75] Lottermoser: *Jour. prakt. Chem.* (2), **68**, 341 (1903); **72**, 39 (1905); **73**, 374 (1906). Cf. Drucker: *Zeit. Kolloidchemie*, **4**, 216 (1910).

[76] Böttger: *Jour. Chem. Soc.*, **36**, 107 (1878); Von Weimarn: *Zeit. Kolloidchemie*, **7**, 92 (1910); **8**, 216 (1911); **11**, 651 (1912). Cf. Pieroni: *Gazz. chim. ital.*, **43** i, 197; Paternò and Megigisciann: 439 (1913).

[77] Svedberg, 349.

[78] *Zeit. Kolloidchemie*, **6**, 238 (1910).

[79] *Zeit. phys. Chem.*, **77**, 423 (1911).

[80] Amann: *Zeit. Kolloidchemie*, **8**, 197 (1911); Galeotti: *Ibid.*, **10**, 149 (1912); Hartwagner: *Ibid.*, **16**, 79 (1915).

[81] Cf. Abegg and Schroeder: *Zeit. Kolloidchemie*, **2**, 85 (1907).

the liquid when the ammonium nitrate is nearly all removed. In alloy work stannic oxide should be washed with dilute nitric acid and not with water. Zinc sulphide is apt to form a colloidal solution when the ammonium salt is washed out,[82] and copper ferrocyanide does the same thing if all the copper sulphate is removed by washing.[83] In fact, Chautard[84] claims that the quickest way to wash a gelatinous precipitate is to evaporate the solution to dryness and heat before trying to wash. Merely evaporating on a water-bath is not always sufficient.[85]

2. *Addition of Peptizing Agent.*—Instead of washing out a precipitating agent, we may add a peptizing agent. Ammonia is very effective in suspending clay,[86] silicic acid is peptized readily by caustic soda,[87] and sulphides are peptized by hydrogen sulphide.[88] In some cases the concentration of the peptizing agent has to be high, and people usually assume the formation of compounds. Hydrous chromic oxide is peptized by caustic potash, and the apparently clear green solution does not contain any appreciable amount of dissolved chromite.[89] Hydrous copper oxide,[90] cobalt oxide,[91] and beryllium oxide form colloidal solutions in alkali. When excess of alkali is added to freshly precipitated hydrous zinc oxide, a great deal of it is peptized; but this precipitates in a short time, leaving a small amount in true solution as zincate.[92] When ammonia is added in excess to a copper salt solution, part of the copper oxide becomes colloidal and part goes into true solution, but we do not yet know the relative amounts.[93]

Chromic oxide makes the oxides of iron, cobalt, nickel, and manganese apparently soluble in caustic alkali.[94] Chromic oxide

[82] Donnini: *Jour. Chem. Soc.*, **66** ii, 318 (1894).

[83] Berkeley and Hartley: *Phil. Trans.*, **206 A**, 486 (1906).

[84] *Jour. Chem. Soc.*, **26**, 527 (1873).

[85] Wright: *Ibid.*, **43**, 156 (1883); Kratz: *Ibid.*, **16**, 121 (1912).

[86] Skey: *Chem. News*, **17**, 164 (1868); **22**, 236 (1870); **34**, 142 (1876). See also Doelter: *Handbuch der Mineralchemie*, **2**, 122 (1912).

[87] Graham: *Jour. Chem. Soc.*, **17**, 324 (1864).

[88] Young: *Jour. Phys. Chem.*, **21**, 1, 14 (1917).

[89] Fischer and Herz: *Zeit. anorg. Chem.*, **31**, 352 (1902); Nagel: *Jour. Phys. Chem.*, **19**, 331 (1915).

[90] Fischer: *Zeit. anorg. Chem.*, **40**, 40 (1904).

[91] Hantzsch: *Ibid.*, **31**, 352 (1902).

[92] Bancroft: *Jour. Phys. Chem.*, **20**, 98 (1916).

[93] Grimaux: *Comptes rendus*, **98**, 1434 (1889).

[94] Northcote and Church: *Jour. Chem. Soc.*, **6**, 54 (1854); Nagel: *Jour. Phys. Chem.*, **19**, 331 (1915).

forms a colloidal solution in ammonia if enough copper salt is present.[95] Stannic acid enables iron oxide to go into colloidal solution in ammonia.[96] Molybdic acid is not precipitated by uranyl salts alone, but is in presence of tungstic acid, which carries it down and which it holds up when present in excess.[97]

The oxides of alumina, iron, cobalt, thorium, and yttrium, when freshly precipitated, are readily peptized by hydrochloric acid[98] or by their own chlorides.[99] In fact, most oxides can be peptized to some extent by their chlorides or nitrates.[100] Ferric oxide has been peptized by aluminum chloride,[101] and freshly precipitated alumina is peptized readily by 8 per cent. acetic acid.[102] It seems probable that any substance, which will carry another into true solution when in sufficient concentration, will be adsorbed by the second, but there is no direct experimental evidence of this. Prussian blue is peptized by oxalic acid or by potassium oxalate.

At high temperatures fused baths peptize metals, forming the so-called metallic fogs[103] which are the cause of the enormous decrease in the current efficiency when the sodium or the aluminum bath is heated too hot.

The action of soap on rouge or carbon black[104] looks like a disintegration; but it is not. If a suspension of carbon black in water be filtered several times through filter-paper, the water will finally run through clear, and the carbon black will be held back by the filter-paper. If a soap solution be poured on the filter, a

[95] Prud'homme: *Jour. Chem. Soc.*, **25**, 672 (1872).

[96] Lepez and Storch: *Monatshefte*, **10**, 283 (1889).

[97] Hitchcock: *Zeit. anorg. Chem.*, **8**, 235 (1898); Wöhler: *Zeit. Elektrochemie*, **16**, 693 (1910).

[98] Müller: *Zeit. anorg. Chem.*, **57**, 311 (1908).

[99] Graham: *Jour. Chem. Soc.*, **17**, 325 (1864).

[100] Fischer: *Zeit. anorg. Chem.*, **40**, 43 (1904); Müller: *Ber. deutsch. chem. Ges.*, **39**, 2857 (1906); *Zeit. anorg. Chem. Soc.*, **52**, 316 (1907); Szilard: *Jour. Chim. phys.*, **5**, 488, 636 (1907).

[101] Schneider: *Ber. deutsch. chem. Ges.*, **23**, 1349 (1890); *Liebig's Ann.*, **257**, 359 (1890).

[102] Bentley and Rose: *Jour. Am. Chem. Soc.*, **35**, 1490 (1913); Rose: *Zeit. Kolloidchemie*, **15**, 1 (1914).

[103] Lorenz: *Van Bemmelen Gedenkboek*, **395** (1910); *Zeit. anorg. Chem.*, **91**, 46, 57, 61 (1915).

[104] Spring: *Zeit. Kolloidchemie*, **4**, 161 (1909); **6**, 11, 109, 164 (1909); Bancroft: *Jour. Phys. Chem.*, **20**, 107 (1916).

black filtrate is obtained and the filter-paper is no longer black. All the carbon black has passed through the filter-paper. The same thing can be done with rouge, except that a red filtrate is obtained instead of a black one. At first sight it seems as though the soap must have broken up the carbon or the rouge into finer particles, which then passed through the filter; but I think that this is erroneous. The filter-paper is porous enough at first to let through the particles of carbon or rouge, as is shown by the fact that some of the suspended matter does pass through the filter at first. The cellulose adsorbs the carbon black or the rouge, and this clogs the filter to such an extent that the pores are not large enough to let the remaining particles through. The soap removes the rouge or the carbon black from the paper because it adsorbs these substances more strongly, and everything, therefore, goes through the paper. That this is the true explanation can be shown in two ways. In the first place, the experiment does not succeed if the rouge or the carbon is too coarse. In the second place, Spring showed that we are dealing with an adsorption of carbon black by filter-paper. If the black filter-paper be reversed and washed with water, the water removes only the black, which is not in immediate contact with the paper.

3. *Mechanical Disintegration.*—If a solid be ground up sufficiently fine, it will necessarily form a colloidal solution for a time. This has been done experimentally by Wegelin[105] in the case of a number of metals. The addition of gelatine makes it easier to disintegrate ductile metals. Since a finely divided solid is more soluble, it is possible that it may go into solution and then precipitate in another form. This seems to happen with quartz. When reduced to an impalpable powder by long grinding, quartz can be converted into colloidal hydrous silicic acid merely by boiling with water.[106]

4. *Electrical Disintegration.*—When a direct current arc is formed under water between two wires, the metal is disintegrated and colloidal solutions of platinum, iridium, palladium, gold, silver, and cadmium may be obtained in this way.[107] Satisfactory conditions are obtained with 30 to 40 volts and 5 to 10

[105] *Zeit. Kolloidchemie*, **14**, 65 (1914).

[106] Desch: "The Chemistry and Testing of Cement," 58 (1911).

[107] Bredig: *Zeit. Elektrochemie*, **4**, 514 (1898); *Zeit. phys. Chem.*, **31**, 258 (1899).

amperes. A trace of alkali in the water causes formation of finer particles, presumably owing to the stabilizing effect of the hydroxyl ion. The disintegration is chiefly at the cathode.

The method is not satisfactory with organic liquids, because too much decomposition of the liquids takes place. Svedberg found empirically that this decomposition could be decreased very much if the current density were made as small as possible.[108] He therefore used an oscillatory discharge from an induction coil with a condenser in parallel or in series. The best results are obtained with large capacity, small self-induction, low resistance, and short arc. By this improved method Svedberg succeeded in preparing colloidal solutions of all the metals, including the alkali metals. Liquid methane, ether, and isobutyl alcohol at low temperature were especially satisfactory with the metals of the alkalies and the alkaline earths. The order of disintegration of some of the metals under similar conditions was found to be Fe, Cu, Ag, Al, Ca, Pt, Au, Zn, Sn, Cd, Sb, Tl, Bi, Pb, the iron being the least rapidly disintegrated and the lead the most rapidly disintegrated. There is no apparent relation either with the order of the boiling-points or with the order of disintegration by cathode rays or canal rays.

5. *Electrochemical Disintegration.*—With a lead cathode in caustic soda solution, the lead disintegrates when the current density exceeds a critical value, and the solution is colored black like ink with fine particles of metallic lead.[109] This is due to the temporary formation of a sodium-lead alloy, which then disintegrates in contact with water. Similar results can be obtained with cathodes of tin, bismuth, thallium, arsenic, antimony, and mercury. E. Müller[110] obtained colloidal solutions of tellurium with a tellurium cathode. This seems to be due to the formation of polytellurides, which break down and set free tellurium. In the presence of oxygen there may also be an oxidation of a telluride. Fischer[111] has obtained metallic copper in the solution by using a high current density with a copper anode in sul-

[108] Svedberg, 424.

[109] Reed: JOUR. FRANKLIN INST., **139**, 283 (1895); Bredig and Haber: *Ber. deutsch. chem. Ges.*, **31**, 2741 (1898); Haber and Sack: *Zeit. Elektrochemie*, **8**, 245 (1902); *Zeit. anorg. Chem.*, **34**, 286 (1903).

[110] *Zeit. Elektrochemie*, **11**, 521, 701 (1905); Haber: *Ibid.*, **11**, 660, 827 (1905).

[111] *Ibid.*, **9**, 507 (1903).

phuric acid. Cuprous sulphate is formed, which breaks down to metallic copper and cupric sulphate. This experiment has not yet been made to give colloidal copper; but this could probably be done if one were to add a suitable protecting colloid. The disintegration of all electrodes by an alternating current when the current density is high is undoubtedly due to the temporary formation and subsequent breaking down of a hydrogen or metallic alloy.[112]

Summary.

In this paper there has been given a discussion of: types of precipitates; theory of peptization; condensation methods; dispersion methods. Under condensation methods there are two subdivisions, in which the stability is due chiefly to the presence of strongly adsorbed substances or chiefly to the low concentration of agglomerating agents. Under dispersion methods the subdivisions are disintegration by removing an agglomerating agent, by adding a peptizing agent, by mechanical methods, by electrical methods, by electrochemical methods.

CORNELL UNIVERSITY.

The Corrosion of Metals by Acids. O. P. WATTS and N. D. WHIPPLE. (*Proceedings of the American Electrochemical Society*, October 3–6, 1917.)—The great economic interests involved in the corrosion of metals make it one of the most important problems which to-day engage the attention of electrochemists. The importance of galvanic couples in the corrosion and protection of metals received early recognition, but it is only in recent years that the whole problem of corrosion has been recognized as being electrochemical in its nature. It was formerly supposed that zinc dissolved in sulphuric acid because the affinity of this metal exceeded that of hydrogen for the SO_4 radical; and that for the action to go on until either the zinc or the acid was exhausted, it was only necessary that the product, zinc sulphate, should be soluble.

Among the many natural phenomena to whose explanation the theory of electrolytic dissociation has been applied is the corrosion of iron. According to this, the formation of a soluble compound is not a prerequisite to the dissolving of a metal by an acid, the metal

[112] Haber: *Trans. Am. Electrochem. Soc.*, **2**, 192 (1902); Van Name: *Zeit. Elektrochemie*, **10**, 303 (1904).

going directly into solution as ions, and any compounds which may be formed being the result of combinations which occur after solution has taken place. From either the chemical or the ionic point of view, an electrolyte is like a room so crowded that no newcomers can enter unless some of those already present pass out to make place for them. On account of the enormous scale on which it occurs, the rusting of iron has received more attention than any other case of the corrosion of metals, and it is admitted by all that oxygen is necessary for the continuation of this process.

In the extraction of gold and silver by the cyanide process, the presence of oxygen is found to be necessary in order that solution of the metals may take place with sufficient rapidity to make the process practical, the effect of the oxygen being to remove from the surface of the ore the hydrogen which is displaced by the metal when it dissolves. If the hydrogen is allowed to accumulate, its presence greatly retards solution. When amalgamated zinc is put into dilute sulphuric acid, zinc begins to dissolve, and displaces hydrogen just as if the metal were unamalgamated; but before the deposited hydrogen has become sufficient in amount to be visible or to escape as gas, the polarization produced by it, and therefore the electrical pressure necessary to deposit more hydrogen, has risen to equal the potential of zinc, when this metal is no longer capable of displacing hydrogen, and its solution ceases. Experiment indicates that the protection of zinc by amalgamation is due to the elevation of the discharge potential of hydrogen brought about by the presence of mercury, and that corrosion is promoted by the addition of an oxidizing agent to the acid. The value of nitric acid as a general solvent for metals is also shown to be due to its being at the same time an acid and an oxidizing agent.

That the inherent nature of the reaction between acids and metals is always the same is shown by experiment. On immersion in an acid, metal begins to go into solution and hydrogen is displaced. But the law of mass action applies here. As hydrogen accumulates, the driving force required to deposit more of this gas increases, and if the potential, solution pressure, or whatever other term may be chosen to designate the relative displacing power of metals in electrolytes, be very low like that of copper or silver, equilibrium is quickly reached and the action comes to a standstill. If the potential of the metal is high, as for zinc and iron, the reaction goes on, the density of the hydrogen film increases to such a point that gas begins to escape, and, as equilibrium has not yet been reached, the reaction continues as is usual in chemical changes when one of the products escapes from the field of action. The effect of an oxidizing agent is to remove one product, hydrogen, and so prevent attainment of the equilibrium which is otherwise quickly reached with the metals of low potential, copper, mercury, silver, etc.

THE SENSITOMETRY OF PHOTOGRAPHIC INTENSIFICATION.*

BY

A. H. NIETZ AND K. HUSE.

IT is well known that when a negative is intensified the intensified deposit is often of a different color from that of the original negative and that this color affects the printing quality of the intensified negative; in fact, some processes of intensification depend entirely upon a change of the silver to some material having a more non-actinic color. For instance, if a negative is bleached to a silver salt and then treated with sulphide solution the silver will be converted into silver sulphide and visually will be more transparent than it was before the treatment, but the color of the silver sulphide deposit will be a brown, having much more opacity for blue light than the silver, and consequently when printed the negative will give a more contrasty print.

While intensification has been dealt with in photographic literature from the chemical standpoint and also from the practical advantages and disadvantages of various methods, very little quantitative work has been done on the effect of the color of the deposit, the only reference we have been able to find being to the work of L. P. Clerc, who measured the printing quality obtained in negatives intensified with Desalme's copper tin intensifier.[1]

In this paper we give an account of a series of measurements made on the effective printing contrast of negatives intensified by various processes, the intensified negatives ranging from those practically neutral in color to very highly colored deposits.

The legitimate function of an intensifier is that of increasing the contrast of a negative, thus acting as a corrective of under-development. Intensification may be necessary from several causes: owing to an error a negative may have been simply under-developed, in which case intensification will correct the error, or, again, if a negative is known to be badly over-exposed,

* Communicated by Dr. C. E. K. Mees. Communication No. 58 from the Research Laboratory of the Eastman Kodak Company.

[1] A Bibliography of work on the subject of intensification published during the last seventeen years is appended to this paper.

then by the use of a strongly restrained developer and short development an image can be obtained in which the gradation will be approximately correct but the contrast will be insufficient, and intensification will then give the proper contrast. Some intensifiers may be used on under-exposed negatives to intensify up weak shadow detail which would otherwise be lost in printing, and thus make it possible to get a print, though in this case the gradation will be incorrect, and no process of intensification can save a serious under-exposure.

In this paper we do not deal at all with such questions as the permanency of an intensified image or the suitability of the process for practical work; the ease of operation, uniformity of the action, capacity for repetition or for reduction, if too heavy intensification is obtained being completely ignored. In many cases the distortion of the scale of the negative by intensification is of little consequence, but if true reproduction of the tones of the subject is desired in the finished print, then the intensifier must be chosen with care, and the results shown in Fig. 5 or Table IV form a useful guide as to the selective action of various intensifiers.

EXPERIMENTAL WORK.

The experimental details of the present work require only brief description. Twenty well-known formulæ were investigated. These are shown in the following table:

A standard Seed 23 emulsion coated on patent plate glass was used. Exposures over a range of 1 : 1000 were made on a non-intermittent sensitometer, and all the plates were developed at 20° C. in a thermostat, in a paraminophenol developer. The development was for such a time that the contrast of the plates, measured by reading visually the densities on a Koenig-Martens photometer, was 0.5. The characteristic curve of the original negatives was determined from a number of plates, and the separate individuals did not differ appreciably from the mean. In all cases the plates were soaked prior to intensification, which was then carried out in duplicate in the various solutions at 20° C. The visual densities were again read and the curves of the intensified negatives plotted. In the case of highly colored images, as, for instance, the uranium deposit, the visual densities were determined by the mean of the readings through complementary

red and green filters, in order to obviate the difficulty of making an intensity match with photometer fields of different color.

Ten of the methods were then chosen as being more or less

TABLE I.

No.	Bleaching solution	Blackening solution	Reference
I.	Mercuric chloride	Ammonia	Bleach according to Bennett, blackener according to B. J. Almanac
II.	Mercuric chloride	Sodium sulphite	Bleach according to Bennett, blackener according to B. J. Almanac
III.	Mercuric chloride	Paraminophenol developer	Bleach according to Bennett
IV.	Mercuric chloride	Schlippe's salt	Bleach according to Bennett, blackener according to B. J. Almanac
V.	Mercuric chloride	Ferrous oxalate	Blackener according to B. J. Almanac
VI.	Potassium bichromate-hydrochloric acid	Amidol developer	C. Welborne Piper, B. J. Almanac
VII.	Mercuric bromide	Amidol developer	Mercuric bromide solution (Monckhoven solution A) from B. J. Almanac
VIII.	Mercuric bromide	Silver cyanide	Monckhoven. B. J. Almanac
IX.	Mercuric bromide	Sodium sulphite	Both from Bennett
X.	Mercuric iodide	Paraminophenol developer	Mercuric iodide according to Bennett
XI.	Acid silver formula in B. J. Almanac		
XII.	Uranium formula, B. J. Almanac		
XIII.	Lead ferricyanide	Sodium sulphide	B. J. Almanac
XV.	Mercuric iodide	Ammonia	Bennett
XVI.	Mercuric iodide	Schlippe's salt	Debenham, B. J., 1917, p. 186
XVII.	Potassium ferricyanide+potassium bromide	Sodium sulphide	Ordinary sepia redeveloper
XVIII.	Cupric chloride	Sodium stannite	Desalme, B. J., 1912, p. 215
XIX.	Potassium permanganate + hydrochloric acid	Caustic hydrochinon	Baker, B. J., 1906, p. 264
XX.	Potassium permanganate + hydrochloric acid	Sodium stannite	

NOTE.—The references above to the "B. J." and the "B. J. Almanac" are to the *British Journal of Photography* and the annual almanac of the same.

typical, and the photographic effect of these intensifiers was studied by the method now described in detail. For this purpose prints were made on a standard material, both from the original and the intensified negatives. The light-source was a 10-watt

tungsten lamp at 110 volts; the illumination falling on the plate was measured by means of a Macbeth illuminometer, and the length of the exposure noted. The times of exposure were such as to just print through some pair of densities on the intensified and original negatives which had received identical exposures in the sensitometer. This fulfils the condition met in practice where prints are made to be comparable by just printing through the same part of the negative (as, for instance, the highest light in the subject) in the case of both the original and intensified negatives. The printing material used was Eastman Motion Picture positive film. Its characteristic curve was determined by exposing it in a non-intermittent sensitometer to the same light-source mentioned above and measuring the illumination as before. This curve represents the mean of five strips. The development of all the prints and sensitometric strips was carried out in the same solution, for the same length of time, at the standard temperature of 20° C., in the thermostat. All these were then read on the photometer as usual, giving us all the data necessary for the study of the photographic effect of intensifiers, namely: (1) the visual densities of the original negative; (2) the visual readings of the intensified negatives; (3) the same for the reproduction (*i.e.*, the prints on the positive film) from the original; (4) those for the reproduction from the intensified negatives; and (5) the characteristic curve of the printing material (positive film). We have, further, the measurements of the actual exposure in candle-meter-seconds, step for step, in the last three cases.

THE VISUAL EFFECT.

A non-selective photographic deposit is seldom met with, although certain developers give negatives which approach it. If we assume the original negative to be neutral and the deposit given by the intensifier not to alter the color, then any increase in visual density will be a direct measure of the photographic effect. Since in most cases neither of these conditions is fulfilled, the visual data are of little practical importance. However, since authors have previously used this method of presenting the facts, especially of depicting the changes in the characteristic curve of the plate, we also include such curves. Fig. 1 shows the effect on the visual plate curve when using, on Seed 23, the various intensifying solutions indicated.

We have also plotted the percentage increase in visual density against the original density of the plate. As before, this represents the actual photographic effect only in the case of neutral

FIG. 1.

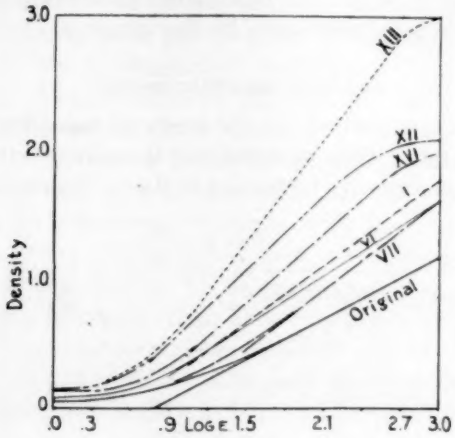
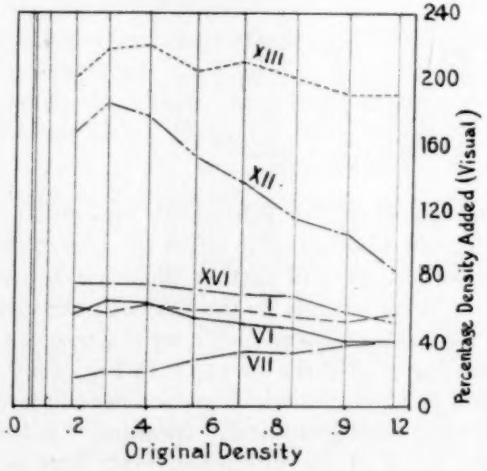


FIG. 2.



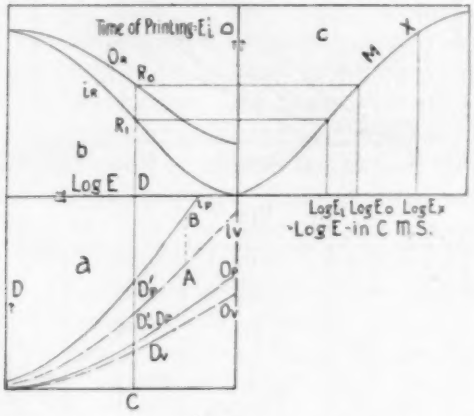
deposits. This is approximately the case with the mercury intensifiers, with the exception of those blackened in Schlippe's salt. The data calculated by such methods for a few representative intensifiers are shown graphically in Fig. 2.

The horizontal scale in the above figure represents actual visual densities of the original plate before intensification. The vertical scale shows the percentage increase in these densities by the different intensifiers. The vertical lines on the density scale indicate the log E scale: *i.e.*, the densities corresponding to exposures increasing geometrically by the factor 2.

THE PHOTOGRAPHIC EFFECT.

In presenting a method for the study of this effect, it is necessary that the reader fully comprehend the conceptions introduced in the preceding paper by Jones and Wilsey. Since we are dealing

FIG. 3.



with a special phase of the subject of reproduction, especially that concerning the photographic effect of colored deposits given by some intensifiers, we will further illustrate and explain these terms, applying them entirely to the case of intensification.

Suppose we have a sensitometric strip whose visual densities plotted against log E give the curve O_v in Fig. 3 *a*. This plate is now intensified in a solution which gives a deposit having selective transmission (*i.e.*, photographically speaking, "colored"). The visual density curve of the intensified plate may be represented by i_v. But now, owing to the color of the deposit and the fact that such deposits may pass either more or less actinic light than if they were neutral, the actual or effective density of some point A on the curve i_v may be assumed to have some other value, such

as B. Similarly, all other points on i_v have other values and form a new curve i_p. This curve then represents the effective printing densities of the plate when used as a negative, and also its effective contrast. For certain well-defined conditions of printing the original and intensified plates, such as we have previously mentioned as agreeing with practice, the densities on i_p may be referred to as the photographic densities of the corresponding points on i_v. This should not be confused with the more strict use of the term by Jones and Wilsey.

Now if we examine the original plate, whose visual curve is O_v, we may find it to be practically neutral, so that its photographic density curve may coincide with its visual curve. But, on the other hand, if this is not true, then the effective density curve may be represented by O_p, and its photographic contrast will be higher or lower than that measured visually. This is usually the case for even the paraminophenol developer used, although metol and amidol [2] give very nearly neutral deposits.

The problem now before us is to devise a method of obtaining these photographic density curves. The method employed is based on the work done on the theory of reproduction by the authors of the preceding paper.

To aid in a more concrete presentation of this method, graphic means will be employed. In Fig. 3, *a*, *b*, and *c*, the curves in 3 *a* are those already described. In 3 *b* are shown the reproduction curves of the two plates, O_v and i_v, these being plotted in such a way that any point on O_R or i_R represents the deposit given by printing through the corresponding density on O_v or i_v, determined by projection downward from the points on O_R and i_R. Thus the heaviest densities on i_R correspond to the lightest on i_v; *i.e.*, by printing through the latter. Fig. 3 *c* is the characteristic curve of the printing medium (positive film), exposed to the same light-source as used in producing O_R and i_R. The density scale is the same throughout, and the exposure corresponding to any value of log E in Fig. 3 *c* is known in candle-meter-seconds. Then for any density x, produced on positive film by light of the quality

[2] We have found that amidol is capable of giving deposits which are photographically blue, namely, that their opacities to white light measured visually are greater than their opacities to the light, which is most active photographically.

transmitted by the negative, we can find the equivalent exposure E_x which produced that density by reference to the log E axis of the curve M. For example, let us find the equivalent amount of light which the density D'_v must have transmitted to produce the density R_i in the print. By projection from R_i to the curve M and thence to the log E axis, we determine directly this value, E_i, and similarly for any other point on the curve i_v.

Let

D_v = the visual density at any particular step on the original plate.

D_p = the photographic density of the same deposit.

D'_v = the visual density of the intensified plate at the same step.

D'_p = the photographic density of the latter.

The problem is to find D'_p, the photographic density of the particular step on the intensified plate, having given the visual density of the original negative, the reproductions from the original and intensified negatives, the curve of the reproducing medium developed in the same manner as the reproductions, and the illumination used in making the reproductions and in exposing the sensitometric strips of the medium. That is, we have given in the figure above, O_v, the visual curve of the original negative; O_R the curve of O_v printed on the medium; i_R, the curve of the intensified strip printed in the same manner, and M, the characteristic curve of the printing material. We must also know the exposure in candle-meter-seconds incident on the negatives in printing, as well as that given the cine-positive in the sensitometer.

Now it will be possible to find the photographic density, D'_p of the point D'_v on the curve i_v. There are two practical methods of solution. The first makes no assumptions as to the selectivity of the deposit on the original, whereas the second assumes that the original negative is neutral; *i.e.*, that $D_v = D_p$.

Method I.

In this method the photographic transmission of the deposit is obtained by measuring the ratio of the equivalent amount of light passed by the given deposit to the total amount incident upon it. As already shown, the equivalent amount of light actually passed by D'_v is determined by projection of the point R_i to the curve M, and thence to the log E axis. This gives E_i (from log E_i), the

equivalent amount of light transmitted in candle-meter-seconds. The exposure used in printing the negative, E'_i is measured by means of an illuminometer in the ordinary way. The photographic transmission, T_i, equals $\frac{E_i}{E'_i}$. From this relation the density is obtained, since $D = \log \frac{I}{T}$, by definition.

We have now found the photographic density D'_p, and in the same manner the other points of the curve i_p may be determined, which is the effective photographic density curve of the intensified negative. Laborious as this method may seem, the figures on an actual case, given below, will show that it is quite practicable.

TABLE II.

$E'_i = 4360$ c.m.s.

Step on negative	D'_v	R_i	E_i	$D'_p = \log \frac{E'_i}{E_i}$
1	0.23	2.03	300	1.16
2	0.25	2.00	285	1.19
3	0.40	1.82	200	1.34
4	0.58	1.47	104	1.62
5	0.76	1.12	58	1.88
6	0.94	0.79	32	2.13
7	1.12	0.50	19	2.36
8	1.30	0.28	10	2.64
9	1.48	0.14	6.2	2.85
10	1.66	0.06	5.1	2.93
11	1.86	0.02	5.0	2.94

The values of the visual and photographic densities for the above case may be compared by consulting the second and last columns. The higher values of the photographic densities are in part due to the ultra-violet absorption of the plate-glass support of the negative.

Method II.

Assume that D_v and D_p coincide; *i.e.*, the original deposit is neutral. Assume, also, that the original and intensified plates were printed for the same time. The problem is to find D'_p with reference to D_v.

Let $T_{D'_p}$ be the photographic transmission corresponding to the photographic density D'_p and T_{D_v} be the photographic transmission of the original density taken, D_v.

Then

$$D'_p - D_v = \log \frac{1}{T_{D'_p}} - \log \frac{1}{T_{D_v}} = \log \frac{T_{D_v}}{T_{D'_p}}$$

But T_{Dv} and $T_{D'p}$ are in the same ratio as E_o and E_i, the exposures derived from the curve M, since E_o and E_i represent the amounts of light passed by D_v and D'_p respectively. Of these, E_o, E_i, and D_v are known, and hence we may say that

$$D'_p - D_v = \log \frac{TD_v}{TD'_p} = \log \frac{E_o}{E_i} = \log E_o - \log E_i$$

This difference between the logarithms of E_o and E_i gives us directly the difference in density between D_v and D'_p. Adding this to D_v gives us D'_p, the photographic density desired.

Table III gives the values obtained from one experiment.

TABLE III.

Step on negative	D_v	log E_O	log E_i	log E_O − log E_i	D'_p
1	0.06	2.06	....	....	0.06
2	0.06	1.98	1.90	0.08	0.14
3	0.11	1.84	1.75	0.09	0.20
4	0.20	1.68	1.55	0.13	0.33
5	0.33	1.50	1.29	0.21	0.54
6	0.50	1.26	1.00	0.26	0.76
7	0.68	1.02	0 72	0.30	0.98
8	0.91	0.78	0.46	0.32	1.23
9	1.14	0.54	0.16	0.38	1.52
10	1.37	0 26	−.19	0.45	1.82
11	1.60	0.04	−.19	0.23	1.83

It is obvious that this method cannot be applied in cases where the original and intensified plates differed greatly in density, as it is here required that the printing times be the same and also that the two negatives be printed equally through some pair of steps, usually the highest density.

We have now all the means for determining the photographic action of different intensifiers, and it is possible to plot for any intensifier the four curves O_v, O_p, i_v, and i_p.

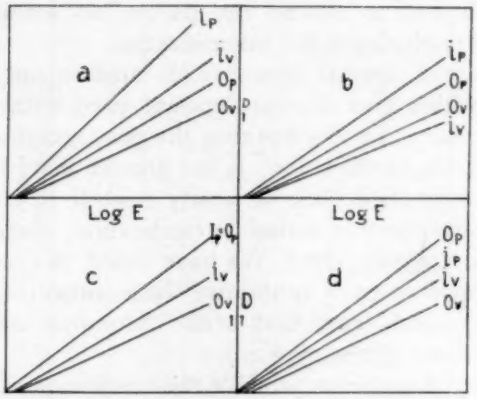
CLASSES OF INTENSIFICATION.

Before discussing this subject it may be well to emphasize the fact that intensification, considered from the chemical and photographic standpoints, represents two quite different conditions, and we may have the first without the latter, or the latter with very little of the first. Chemically speaking, intensification means increase in density by the addition of something to the deposit. Photographically, intensification implies that the effective con-

trast of the original is changed, which may occur by a change either in the color or in the arrangement of the grains, aside from increase in the bulk of the deposit. It is readily seen that we may have chemical addition to the various densities without changing the effective contrast, the added density only necessitating longer exposure. This kind of intensification is of no advantage. This point will be made clearer by the following generalizations from our experimental data. We will consider all cases of intensification, whether they result in true photographic intensification or not.

Applying the methods previously outlined, we have found that, in general, so-called intensification may be of four kinds,

FIG. 4.



as shown in the generalized curves, Fig. 4, *a*, *b*, *c*, and *d*, where the relative positions of the curves may be somewhat exaggerated to illustrate the point.

In Class *a*, Fig. 4, we have the normal case of an original negative of not too high color (but still sufficient to give a higher photographic than visual contrast), intensified by a method giving a fair degree of color in the deposit. There are both visual and photographic intensification. Such methods include Desalme's copper-tin intensifier, mercuric iodide with Schlippe's salt, mercuric iodide with an alkaline developer, and uranium.

In a special case of this class, $i_p = i_v$; *i.e.*, the intensifier gives neutral deposits. Such cases are mercuric bromide with amidol,

and chromium-amidol used with an original neutral negative, in which case $i_p = i_v$ and $O_p = O_v$.

This is the most general and most useful class of intensifiers. Some others which fall in this class, if used with neutral negatives, are mercuric chloride used with various blackening agents, such as ammonia, sodium sulphite, ferrous oxalate; Monckhoven's; acid silver; and mercuric iodide with ammonia. Further relative data concerning these intensification methods will be given.

Class *b* shows visual reduction but photographic intensification. This occurs, for instance, when nothing is added to the original silver but the silver is changed to silver sulphide, as by bleaching in ferricyanide-bromide solution and blackening in sodium sulphide. Here there is a slight loss in visual density, but, as the deposit is colored and passes less actinic light than before, there is photographic intensification.

Class *c* is a special case which applies only to certain intensifiers, which give neutral deposits, used with negatives of rather high color. In this instance the photographic contrast of the original (due to the color) is far greater than its visual contrast. The intensified plate is nearly neutral in color, and, although perhaps there is visual intensification, there may be no photographic intensification. We have found this to be true with plates developed in pyro containing little sulphite (thus giving heavy color), and intensified with chromium amidol, which bleaches out some of the pyro color.

It has been possible to produce the conditions shown in Class *d*, in which we have visual intensification but photographic reduction. This was actually experimentally obtained by intensifying a pyro negative of high color in Baker's permanganate-caustic hydrochinon formula. There was slight visual intensification, but, since the pyro color was removed by the bleach, redevelopment gave a nearly neutral deposit of lower photographic contrast than the original negative. It should not be inferred that this method does not give intensification, since with neutral negatives it is quite satisfactory, giving some increase in contrast.

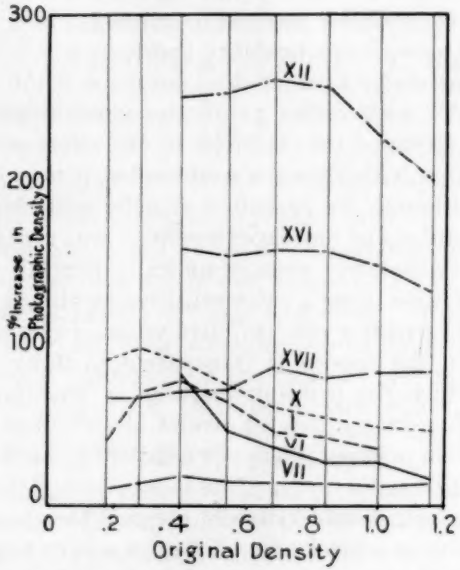
In the above curves, and the consideration of them, when it is indicated that, for instance, $i_p = O_p$, it does not follow that the curves are necessarily coincident, but only that they are of equal contrast and otherwise similar. This is logical, since these nega-

tives would be exactly equivalent in printing, although one would require longer exposure than the other.

CHARACTER OF THE PHOTOGRAPHIC INTENSIFICATION.

A method of interpreting the data, analogous to that used in showing the visual effect (Fig. 2), is applied in Fig. 5, where the percentage increase in photographic density is plotted against the value of the original visual density. The ordinates represent the percentage increase and the abscissæ are the same as in Fig. 2.

FIG. 5.



A line parallel to the horizontal axis would indicate strictly proportional intensification, the same relative amount being added to each density, thereby acting to increase the contrast in the same way as longer development would. Most intensifiers approach this condition rather closely. One of the best methods in this respect, giving also vigorous intensification, consists in bleaching the negative in mercuric iodide, washing very thoroughly, and blackening in a fresh, filtered solution of Schlippe's salt (XVI).[3]

[3] This intensifier is the one which Mr. Debenham suggested we investigate. (*B. J.*, 1917, p. 186.)

The mercuric bromide and amidol method (VII) gives proportional, although low, degree of intensification. This, however, gave the most nearly photographically neutral deposit found. Desalme's copper-tin intensifier (XVIII) deserves special mention. This was investigated by L. P. Clerc,[4] who was one of the few to consider the necessity of measuring the photographic effect and to devise means to this end. However, his method differed radically from ours, and was applied only to one or two cases, notably the copper-tin intensifier mentioned above.

We also find that this combination gives photographically proportional intensification of fair degree, and it appears that it might be a very desirable method to employ. But, as we stated originally, the general practicability (permanence, color of image, etc.) of any particular formula does not come within the scope of this paper. We wish rather to discuss intensification primarily from the standpoint of the character of the affect produced.

In connection with Desalme's intensifier, it may be of interest to note that although the deposit is visually quite highly colored, under the conditions of our experiments, it was repeatedly proved to be in effect absolutely photographically neutral. This would not be true were we using a color-sensitive printing medium. But positive film is sensitive only to ultra-violet, violet and blue, and it happens that the deposit is transparent to those wave-lengths of light to which the printing material is sensitive, whereas a yellow or yellow-brown deposit would absorb them. Hence the color of a deposit may not always be assumed to increase its photographic density.

Using a permanganate-hydrochloric acid bleach with a sodium stannite solution as a blackener (XX), on a pyro negative, we obtained a strongly colored image which showed visual intensification and still greater photographic effect.

From our experiments it is apparent that the color of the intensified deposit, as well as the degree of intensification, depends on the character of the original deposit, the latter being a function of the type of emulsion and the developer used.

COLOR COEFFICIENTS OF INTENSIFIERS.

It will be necessary to again refer to the paper by Jones and Wilsey, in which this term is defined. Practically, the color co-

[4] *B. J.*, 1912, p. 215.

efficient of an intensifier is that factor by which we must multiply the visual contrast value of the intensified plate to obtain its photographic contrast. For example, assume the visual contrast of the negative to be 0.8. If the color coefficient of the intensifier employed is 1.5 under the conditions of the experiment, then the effective photographic contrast of this negative will be $1.5 \times 0.8 = 1.2$.

An application of the conception of color coefficient is made in the following, for which the reader is again referred to Fig. 3 *a*. Here the ratio of the densities D'_p and D'_v is the selectivity coefficient for the given density; that is,

$$\frac{D'_p}{D'_v} = \text{selectivity coefficient of density.}$$

The ratio of the slopes at the points D'_p and D'_v, that is,

$$\frac{\frac{d\,D'_p}{d\log E}}{\frac{d\,D'_v}{d\log E}},$$

is defined as the selectivity gradient coefficient.

In any case where the value of the selectivity gradient coefficient is constant over a range of values of $\log E$, we may consider the plate as having a color coefficient. Moreover, if the plate curves have sufficient straight line to determine a definite gamma, the color coefficient is the ratio of the gammas, photographic and visual. For this special case selectivity gradient coefficient = color coefficient = $\frac{\text{photo gamma}}{\text{visual gamma}}$. These conditions are usually fulfilled by curves obtained by intensification methods. The measurement of the gammas of our curves gives us sufficient data to tabulate, for various intensifiers, the values of their color coefficients. This is simply a factor for converting the visual into the photographic contrast by taking into account the color of the deposit. We will include also a factor showing the degree of increase in contrast. This is given in the third column of the table below, and represents the ratio $\frac{\text{phot. gamma of intensified plate}}{\text{phot. gamma of original plate}}$. The rule of reproduction states that the photographic gamma of the negative multiplied by the gamma to which the reproducing medium is developed is equal to the gamma of the reproduction. In the fourth column of the following table is given the calculated value of the photographic gamma of the intensified plate;

in the fifth, the gamma to which the reproducing medium is developed; in the sixth, the observed gamma of reproduction.

It should be emphasized that the following values of the color coefficients apply only to the set of experimental conditions here met with, and that they will vary with the plate used, the character of the reproducing medium, and the quality of the light-source. But these values are useful as a means of comparing the different methods of intensification.

TABLE IV

1 Intensifier	2 Color coefficient	3 $\frac{\gamma i_p}{\gamma O_p}$	4 γi_p	5 γM	6 Obs. γ of reprod
VII	1.00	1.15	0.78	1.10	0.85
I	1.05	1.15	0.78	1.10	1.03
VI	1.00	1.45	0.44	1.38	0.53
XVI	1.90	2.50	1.70	1.10	1.68
XIII	1.17	2.28	1.54	1.10	1.55
XII	2.52	3.50	2.40	1.10	2.52
XX	1.43	2.05	0.86	1.38	1.14
XVIII	1.00	1.93	0.54	1.38	0.74
XVII	1.60	1.33	0.48	1.38	0.54
X	1.40	1.23	0.84	1.10	1.00

For the formula reference for any of the above see Table I.

The use of the table is illustrated in part by a case of the three intensifiers VI, XVIII, and XVI (Chromium-amidol, Desalme's, and mercuric iodide with Schlippe's salt). Here we have three intensified plates, of which the first is visually neutral and the other two colored. Now the table shows (column 2) that, in the case of XVIII, the color is not effective in still further increasing the contrast, since its color coefficient is 1.00, but that with XVI the color almost doubles the effective contrast (color coefficient 1.90). The relative total degrees of intensification (increase of *contrast*, not density) are given by column 3, where we find the values to be respectively 1.45, 1.93, and 2.50. Thus XVI is the most powerful of the three.

It would be interesting to compare all intensifiers in this manner, but because of the mass of data required only representative ones were taken. Most of the mercury intensifiers are quite fairly represented by I and VII. The acid silver, Wellington, and copper intensifiers were not practicable on the emulsion used, so that unfortunately they are entirely omitted.

DISCUSSION—PRACTICAL.

It is hoped that the reader will find sufficient information in the foregoing to give him some idea as to the adaptability of the various forms of intensification. To come down to practical considerations, suppose we take four typical negatives requiring intensification, bearing in mind that the primary object of this process is the increase of photographic contrast in the negative to produce prints of the best quality possible. Four cases of negatives requiring such treatment are: (1) average landscape, over-exposed, and under-developed to save the negative; (2) average landscape, under-exposed, but having faint detail—*i.e.*, the exposure of the plate lies entirely on the toe of the H. and D. curve; (3) a line subject in black and white—typical dry-plate process work; (4) a pyro negative of high color of any of the preceding kinds.

In the first case the intensifier must be strictly corrective of under-development, thereby giving fair increase of contrast. If the negative is practically neutral, VI and X would be desirable; XVIII or XVI where more vigorous action is desired—that is, in cases of very little development.

In case two it is necessary to increase the contrast to a considerable extent. Here XVI or XII is especially applicable, the first being probably preferable.

In case three it is usually desirable to have a method capable of repetition, as well as one giving excessive density with clarity of high-lights. Monckhoven's intensifier is usually recommended. Lead could be used, but is likely to give veiled high-lights.

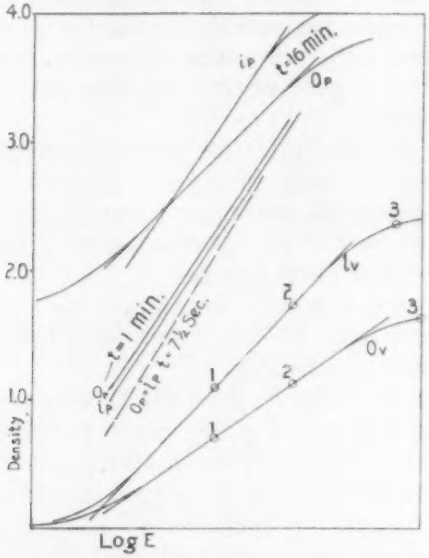
Case four requires an intensifier of fairly high color coefficient, or, in general, one giving high intensification, particularly as the pyro color is likely to be partially or wholly removed by almost any of the processes. For this type the proper effect is given by XVI, XX, or XII.

DISCUSSION—ERRORS IN METHODS.

As previously stated, the term photographic density has been used rather loosely throughout the present paper in lieu of effective printing density. These values, also, are not in most cases the true photographic densities and are not found by the method set forth by Jones and Wilsey. But, for the problem under consideration and the definite materials used, the values obtained

include the errors due to the failure of the given sensitive materials to act in accordance with known photochemical laws. A source of error of primary importance is the failure of the reciprocity law on the printing material used. This has not been thoroughly investigated, but sufficient evidence has accumulated to show that we are here concerned with it. This came about by the great difference in exposure required for the original and the intensified plates, due to the color of the latter; that is, the same densities on the reproductions of the two may have been caused

FIG. 6.



by widely different exposures, $I_1\ t_1$ and $I_2\ t_2$, and these exposures may be in a different ratio from that given by reference to the curve of the printing material. Had it been possible to vary the intensity (keeping constant quality) to give the necessary exposures and to keep the time constant in the printing of both original and intensified negatives, this error would have been minimized. Further, if we could have kept the time constant and could have varied the intensity so as to give, through every deposit, an equal density on the positive film, we should have the conditions for measuring the relative true photographic densities. But practically this would not give the reproduction of the

subject, which is the aim, and the calculations would not actually apply to ordinary printing. We have, therefore, employed the empirical methods detailed above, and these give what are, no doubt, fair comparisons.

Other factors which should be taken into account are the color-sensitiveness of the printing medium and the variation of gamma with the wave-length of the light incident on this material. A full discussion of the errors involved through these causes is not the purpose of this work. Nevertheless, we investigated several cases, in so far as these conditions applied to our experimental work. An extreme case is shown by Fig. 6.

Two strips, an original highly colored pyro strip (O_v) and the same intensified by chromium-amidol to a much more nearly neutral deposit (i_v), were printed side by side to the same intensity for three different lengths of time, so as to bring the exposures on different portions of the H and D curve, as shown by the circles marked 1, 2, and 3, which indicate the highest density printed through. Had the errors due to the failure of the reciprocity law, the color sensitiveness of the material, and the gamma-wave-length relation not been involved, the three sets of experiments should have given identical values for the contrast and photographic densities. For the two lower times of printing, the photographic curves of the original and intensified plates are practically identical. On now printing sixteen times as long, the values are somewhat different, and the contrast of the pyro (original) strip has been reduced about thirty per cent. This latter effect has been repeatedly observed by Wilsey. However, this is an extreme case, and ordinarily, by printing through densities well up on the curve, and giving such exposures (with not too low intensity) that the reproduction lies almost entirely within the straight-line portion of the curve of positive film, these errors are in part avoided.

The writers wish to acknowledge their thanks to Mr. Alfred Hargreave, who assisted greatly in the experimental work.

In conclusion, an abridged bibliography is given covering some of the most important papers on intensification published within the last two decades.

ROCHESTER, N. Y.,
October, 1917.

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NOTES FROM THE U. S. BUREAU OF STANDARDS.*

A METHOD FOR TESTING CURRENT TRANSFORMERS.[1]

[ABSTRACT.]

THIS paper describes in detail a method for testing current transformers. This is a method which will be found useful in commercial plants where delicate laboratory equipment is not available and where large numbers of transformers must be tested rapidly and with moderate accuracy. Two of the most convenient of the possible modifications of the general method are described in detail.

SPECIFIC HEAT OF LIQUID AMMONIA.[2]

[ABSTRACT.]

THE Bureau's investigations of refrigeration constants have included the careful study of the thermal properties of ammonia. Such calorimetric data are of primary importance in the computations of tables adapted to the needs of the refrigeration engineer. The determination of the specific heat of liquid ammonia has been attended with considerable difficulty, but the progress in artificial refrigeration has made it a matter of great importance. The research gives the specific heat through the range $-45°$ to $+45°$ C. within one part in a thousand. The results are tabulated for convenience in use.

LATENT HEAT OF PRESSURE VARIATION OF LIQUID AMMONIA.[3]

[ABSTRACT.]

THIS paper describes the research of the amount of heat needed to neutralize the temperature change of a substance with a definite change of pressure. This change is sufficiently large to be taken into account in actual calorimetry. This constant was determined by three independent methods with satisfactory concordance of results.

* Communicated by the Director.

[1] Scientific Paper No. 309.

[2] Scientific Paper No. 313.

[3] Scientific Paper No. 314.

LATENT HEAT OF VAPORIZATION OF AMMONIA.[4]

[ABSTRACT.]

This paper gives detailed description of the calorimeter designed to determine the latent heat of vaporization of ammonia. This important refrigeration constant was determined through the temperature interval −42° to +52° C. At 0° the latent heat is 301.8 calories per gramme. The results of 34 separate determinations agree with the mean within one part in one thousand.

GAS INTERFEROMETER CALIBRATION.[5]

[ABSTRACT.]

THE Rayleigh-Zeiss gas interferometer, which finds numerous applications in precision and technical gas analysis, is usually calibrated by means of gas mixtures analyzed by chemical methods. The new method here proposed requires only the use of a pressure gauge and a knowledge of the refractive indices of the gases for which the calibration is desired. It is based upon the relation between the density and the refractivity of a gas and the relation between the composition and refractivity of gas mixtures.

DURABILITY OF CEMENT DRAINTILE AND CONCRETE IN ALKALI SOILS.[6]

[ABSTRACT.]

THE report covers a coöperative investigation, under the auspices of the Bureau of Standards, into the disintegration of concrete when exposed to strongly alkalined soils and waters in the arid regions of the western part of the United States. In some cases well-fabricated structures are attacked. In other cases the structures do not appear to be affected by the salts. The purpose was to discover, if possible, the causes of such action and to ascertain the best methods of avoiding deterioration. The paper shows that the use of cement is still experimental, that porous tile are especially liable to attack, that even dense tile are subject to surface disintegration. The action seems to increase with sulphate and magnesium content. Rather full

[4] Scientific Paper No. 315.
[5] Scientific Paper No. 316.
[6] Technologic Paper No. 95.

data are given and the paper is well illustrated with photographs, diagrams, and graphic charts.

SOME UNUSUAL FEATURES IN THE MICROSTRUCTURE OF WROUGHT IRON.[1]

[ABSTRACT.]

WROUGHT iron is usually described as being of a very simple structure as revealed by the microscope, as compared with many of the alloys in commercial use. A study of the microstructure of a series of commercial wrought irons carried out at the Bureau of Standards, however, has shown the occurrence of some very peculiar and unusual variations in structure in such material. Many of the ferrite crystals, when properly prepared and etched for microscopic examination, show a decidedly banded structure instead of the homogeneous appearance usually described. This unusual structure is to be attributed to a relatively high phosphorus content in such portions and to a non-uniform distribution of this element. Although most specimens showing these unusual features of structure are of a rather poor grade, they are not characteristic of low-grade iron in general. The probable relation between such microstructural features and "fatigue" failure of such material is suggested.

GAS-MANTLE LIGHTING CONDITIONS IN TEN LARGE CITIES IN THE UNITED STATES.[2]

[ABSTRACT.]

FROM a careful inspection of about 4500 gas-mantle lamps in service in ten cities a summary of the condition of mantles, glassware, pilot light, and other particulars was made in order to determine to what extent the customer benefited through periodic maintenance service. By those observations it is found that a lamp not on regular maintenance is likely to be defective five and a half times as frequently as a lamp which is regularly maintained. Also, it is shown that, on the average, one in three of the lamps on regular maintenance was not in good condition, whereas the defects noted in the lamps not so maintained average more than one for every lamp.

[1] Technologic Paper No. 97.
[2] Technologic Paper No. 99.

TYPICAL CASES OF THE DETERIORATION OF MUNTZ METAL (60:40 BRASS) BY SELECTIVE CORROSION.[9]

[ABSTRACT.]

THE paper reports the study of selective corrosion of Muntz metal, a material having a variety of industrial uses. The selective corrosion is illustrated by four types, including tubings, sheets, and forgings. The metal becomes red in color, very weak, and brittle by this type of corrosion. The condition favorable to such corrosion is the accelerating effect of the closely adhering deposits of chloride resulting from the attack of the metal. Other conditions accelerate the corrosion, such as contact with the more electronegative constituents, increase of temperature, and service stresses.

COMPARATIVE TESTS OF PORCELAIN LABORATORY WARE.[10]

[ABSTRACT.]

PRESENT-DAY conditions have brought upon the market several new or heretofore little known makes of chemical laboratory porcelain. In order to get an idea of their comparative value, as well as to learn just to what extent the opinion is justified that porcelain is highly resistant to the action of chemical reagents, a series of tests was made. Only five kinds could be obtained: two American, two German, and one Japanese.

When heated to 200° C. with paraffin and cooled by floating on water at room temperature, there were no failures. At 225° there was breakage of one German ("Bavarian") and both American wares.

Sudden heating in the flame of a Fletcher burner of the Méker type caused either breakage of the kinds that failed in the cooling test, or simply a cracking of the glaze when hot pieces were picked up with tongs.

When digested for two periods of six hours each with hot, 10 per cent. sodium hydroxide solution, the losses in weight were not large, although greater than with any of the other reagents used. The losses for the American wares (Herold or Coors, and Guernsey) and for the Bavarian ware amounted to about 5 mg. for 80 mm. dishes. They were nearly filled by the 50 c.c.

[9] Technologic Paper No. 103.
[10] Technologic Paper No. 105.

of solution used. The losses for the Royal Berlin and the Japanese (" S. C. P.") were about 2 mg., except that one of the Berlin dishes lost 5.5 mg.

Digestion with 10 per cent. sodium carbonate solution for 14 hours and with concentrated sulphuric acid nearly at its boiling-point for three hours caused losses of less than 1 mg., or even apparent slight gains.

The glaze was attacked to a surprisingly small degree when the dishes were subjected to the following treatments in succession. First, 30 gm. of sodium nitrate was kept just at its melting-point for two hours, after which the dishes were washed and dried. The same amount of the salt was then slowly heated until a piece of charcoal floating on it caught fire at a temperature considerably above the melting-point. After cleaning and drying, 33 gm. of a mixture of 30 gm. of the nitrate with 3 gm. of sodium carbonate was kept just at its melting-point for two hours. The dishes were cleaned, soaked in water over night, dried, and weighed. With the excepton of a Japanese dish which then weighed 1.2 mg. less, the combined losses ranged from 0.3 to 0.6 mg.

Ferric hydroxide, spread in a thin layer over the bottom of the dish and ignited strongly, caused staining of the glaze. Digestion with hydrochloric acid (1 : 1) completely removed the ferric oxide when digested for three-quarters of an hour on the steam-bath. This test was made because it was thought that a comparatively easily soluble ferric silicate might be formed, but the slight losses, none of which was greater than 0.2 mg., showed that this is not the case.

In brief, the five kinds of porcelain are about equally resistant to the action of reagents, but only the Japanese and Royal Berlin wares successfully withstood sudden changes in temperature.

SAFETY FOR THE HOUSEHOLD.[11]

[ABSTRACT.]

THE safety of the home is the subject of a new pamphlet just issued by the Bureau of Standards, Department of Commerce, entitled " Safety for the Household, Bureau of Standards Circular No. 75." An interesting account of household hazards is given. The topics are discussed clearly in a manner which

[11] Circular No. 75.

would afford a basis for popular education in "Safety First." The dangers from electricity, gas, fire, lightning, household chemicals, and the other common causes of accident are recited and many actual cases are described. The purpose is to aid in removing needless risk and fear, and to develop intelligent caution where the hazard cannot be entirely avoided.

The hazards of the home have increased in modern times from the service of gas and electricity and the use of such dangerous articles as matches, volatile oils, poisons, and the like. The use of energy in the home necessarily involves some risk, which intelligent planning and care will reduce to a minimum.

Caution alone is not enough, since many of the dangers are not even suspected. The nature of such unknown hazards must be made plain. The circular emphasizes the seriousness of some of the risks not generally known, gives simple cautions, and aims to guide the formation of habits of carefulness. The circular also suggests effective home equipment to minimize the risks involved, and aims to encourage public measures to provide safety for the household and community.

It is intended, not to increase fear of accident, but rather to remove the causes and the need for alarm. The sense of safety to be gained by observing these cautions would alone justify the careful study of this new circular. This circular completes the series of three popular household circulars which deal with measurements, materials, and safety. These form a valuable addition by the Bureau of Standards to the literature on household management.

The appalling loss of life from avoidable causes and injury to person and property make the pamphlet especially timely. It is believed that thousands of human lives could be saved and accidents reduced to the minimum if the precautions suggested are followed. Copies of this circular can be purchased at a nominal cost of 15 cents per copy from the Superintendent of Documents, Government Printing Office, Washington, D. C.

GAS TESTING.[12]

THIS circular may be regarded as a supplement to Bureau of Standards Circular No. 48, "Standard Methods of Gas Testing." The correction tables are arranged in a sequence most

[12] Circular No. 65.

convenient for use in connection with the proposed record sheet. The record forms for calorimeter tests which are shown in the circular have been used for some time and found to be complete and convenient. It is hoped that these forms will be adopted wherever possible, so that there will be greater uniformity in operating methods and the records used. The Bureau is willing to loan the original plates for preparation of electrotypes for these blanks to any one desiring to print them.

Mineral Springs of Alaska. Anon. (*U. S. Geological Survey Press Bulletin*, No. 349, December, 1917.)—Hot springs are widely distributed in Alaska, many of them yielding water that is near the boiling-point and remaining unfrozen the year round. During the Russian occupation of the territory primitive bathing-houses were built at several hot springs, notably near Sitka, and the hygienic value of the springs was recognized. In recent years more elaborate bathing establishments have been constructed at several accessible hot springs, but some that are more difficult of access are occasionally visited by prospectors. The demand for more accurate information about the qualities of the thermal waters led to an investigation whose results are set forth in a recent publication of the United States Geological Survey, Department of the Interior—"Mineral Springs of Alaska," by Gerald A. Waring (Water Supply Paper 418).

To obtain material for this report Mr. Waring spent the field season of 1915 in Alaska. He examined 23 springs and obtained notes on 37 others whose existence was not before known to the Survey. Among the springs described by Mr. Waring are a number that yield carbonated water, and others whose water is strongly sulphuretted or salty. More hot springs have been found in southeastern Alaska than in the interior, perhaps because this part of the territory is best known, and relatively few have been found in northern Alaska. Nevertheless, the report describes hot springs at 21 places in the Yukon Basin and at 5 in Seward Peninsula. The report is illustrated by sketch maps that show the location of many of the springs.

The quality of the spring waters was determined by analyzing samples collected by Mr. Waring, and is discussed in connection with their manner of occurrence and source.

The report contains also a brief chapter on the chemical character of some of the surface waters, by Richard B. Dole and Alfred A. Chambers, who have brought together all the available analyses. Most of the analyses represent samples collected by exploring parties in 1914 and 1915. The discussion of the quality of the waters of the Yukon is based on samples collected daily at Anvik from August

23, 1915, to April 19, 1916, and from June 14 to August 16, 1916. Analyses of these samples will form part of a special report on the quality of the surface waters of Alaska.

Copies of Water-Supply Paper 418 may be obtained without charge by applying to the Director, United States Geological Survey, Washington, D. C.

Accommodation and Chromatism of the Eye. ANON. (*The Optical Journal and Review of Optometry,* vol. 41, No. 2, p. 94, January 3, 1918.)—The human eye, because of its power of accommodation, is a refractive system with a mobile focus. A lens has no mobility of focus at all. The eye that is completely presbyopic also has no mobility of focus, and when a lens is prescribed for the use of a person completely presbyopic, there can be no mobility of focus. Sometimes elderly persons demand glasses with which they can see equally well far and near. If they do not still have sufficient accommodation, this demand cannot be met. Those who take this stand will be more easily convinced that they are asking impossibilities when they are told that what they need is another pair of eyes; that the ability to focus far and near is not a property of the lens, but of the human eye, which is lost in later life. When this power of the eye is lost, glasses cannot restore it; all the glasses can do is to make vision clear for just one point, far or near.

Chromatic aberration is not noticeable in the eye under usual conditions, and yet the retinal image of any bright object is not a simple image. It is multiple in nature and made of several different colors. The reason we do not see the colors is because the eye is very sensitive to yellow rays and much less so to all the others, the result being that we unconsciously disregard all but the image formed by the yellow rays.

By looking at the small bright light through glass that only passes red and violet light, as for instance cobalt-blue glass, and at the same time wearing a correction that keeps the accommodation relaxed, we can measure the chromatism of the eye. Using the cobalt-blue glass in this way, and focussing for the violet, which puts the red out of focus, we compare the width of the red border to the light with the width of the light, and then make a calculation on the basis of the diameter of the pupil of the observing eye, the result of which will express in diopters the amount of chromatic aberration, which is usually found to be about 1.50.

While, as a rule, a person is not conscious of colored borders to bright objects, yet there are some exceptions where, for instance, the letters of test charts are seen bordered with colors. Usually in such cases the sight is slightly blurred, and removing the blur causes the colors to disappear. When this is not the case, there is no remedy for the condition; the subject must become accustomed to his chromatism and learn by practice to disregard it.

NOTES FROM THE RESEARCH DIVISION, ELECTRICAL ENGINEERING DEPARTMENT, MASSACHUSETTS INSTITUTE OF TECHNOLOGY.*

EDGE EFFECT IN COPPER BARS AT ELECTRIC-LIGHTING FREQUENCIES.

MEASUREMENTS have been made of the extra resistance due to non-uniform current density in large copper bars carrying alternating currents at 60 and also at 25 cycles per second. The bars were loaned for the test by the courtesy of the General Electric Company. They were in lengths of 6.1 metres (20 feet) and of cross-section 102 mm. × 6.35 mm. (4 inches × ¼ inch), such as are commonly employed in bus-bar construction behind the low-tension switchboards of central stations supplying electric light and power. Tests were made of the effective resistance offered by simple rectangular loops of these bars, connected end to end by special standard metallic but non-magnetic clamps. The distance between the going and returning sides of the loop was kept at 60 cm. (23.5 inches). The length of the loop was 17.8 metres (58.3 feet) when testing single bars in series. The total direct-current resistance of this loop, including 36 metres of bar and the clamp connections, was 955 microhms at 20° C. On account of this very low resistance, difficulty was experienced in measuring the alternating-current effective resistance with the necessary precision. Three different methods of measurement were used, and many trials had to be made before the results of all three could be found in satisfactory agreement. After about six months' testing and comparison, the following concordant results were obtained with alternating currents of from 100 to 350 ampères:

Cycles/second frequency	Bar temperature	R'/R Resistance ratio
60.8	29° C.	1.3
24	29° C.	1.1

These results indicate that the edge effect in such large copper bars is of considerable practical importance at ordinary lighting and power frequencies. It is commonly supposed that at 60~ the extra alternating-current resistance in such conductors is trivial.

* Communicated by the Director.

In the case of these bars, however, the effective resistance to alternating currents over and above their direct-current resistance was, according to these results, 30 per cent. at 60.8~and 10 per cent. at 24~. This relatively large increment in effective resistance accompanying alternating-current flow is almost entirely attributable to edge effect. The skin effect in the bars is negligible at these frequencies. Thus the formula for skin effect in an indefinitely wide sheet, as originally developed by Lord Rayleigh, shows that the extra resistance of an indefinitely wide bar 6.35 mm. thick would be only 0.1 per cent.; or the resistance ratio would be only 1.001 at 60~and 29° C. In such a 6.35-mm. sheet the alternating-current density would be nearly uniform at all depths below the surface. The alternating-current density in the surface skin for 60~would not be much greater than that at the midplane 3.175 mm. deep. In a bar 102 mm. wide, however, the alternating-current density near the edges is much greater, at 60~ than at or near the middle of the width. The alternating current distributes itself in such a manner as to crowd toward the edges of the bar and to denude the central areas. The phenomenon of edge effect is merely a particular aspect of skin effect. In each case the current avoids the central areas and crowds into the remote outlying regions of the cross-section. Circular copper rods of the same cross-section as these bars (645 sq. mm. or 1 sq. inch) would have, at 60~and 25° C., a resistance ratio R'/R of 1.13, or only 13 per cent. extra resistance due to skin effect, less than half the extra resistance found in the bars at this frequency. Of course, such equisectional rods, on the other hand, would have much smaller cooling surface than the bars, per metre of length, and would therefore heat up much more with powerful alternating currents. In cases where it was considered important to reduce the extra resistance of edge effect, it would be possible to do so by using a tubular section for the conductors, augmenting the diameter and reducing the thickness of the tube wall until the desired limit had been obtained. Such tubes are naturally devoid of edge effect, and only skin effect has to be considered with them. From mechanical and structural standpoints, such large tube busbars might be very awkward to employ.

Some further measurements were made with various shorter rectangular loops made up of these copper bars in parallel groupings. The largest resistance ratio found was 2.2, at 61~and

27° C., in the case of a loop 4.9 metres long (19.3 feet), with its sides 5.1 cm. (2 inches) apart. Each side of this loop was composed of three of these copper bars in parallel, clamped together at the ends, over spacing pieces to keep the individual bars 6.35 metres (0.25 inch) apart. The aggregate conductor was thus 102 mm. wide × 31.8 mm. thick (4 inches × 1.25 inches). The alternating testing current was over 1000 ampères in this case. With the same 3-bar loop broadened out to a separating distance of 63.5 cm. (25 inches) between the sides, the resistance ratio R'/R fell off to 2.0 at 61 ∽ and 25° C.

Pipe Corrosion in Domestic Service. T. F. PAYNE. (A. M. Byers Company, Bulletin No. 30, Pittsburgh, September, 1917.)—The rapid rusting of water pipes in the Pittsburgh district, especially those carrying hot water, has frequently been commented on, and in the beginning of 1917 the subject was taken up for discussion and investigation by the Pittsburgh Board of Trade. In that respect Pittsburgh is not different from most other large cities in the United States, where similar complaints are common. So far, however, no systematic investigation had been made by a house-to-house canvass of buildings to ascertain the difference in life between different kinds of pipe. The A. M. Byers Company, therefore, arranged for such an investigation with the object of determining all the pertinent facts which might aid property owners in meeting the rust question in the most efficient manner.

After several unsuccessful attempts to obtain accurate data from private residences and other buildings, it appeared, for many reasons, that apartment buildings offered the best field for investigation, and observations in 125 apartment buildings were recorded. While the conditions of service vary to a great extent according to the size of pipe used, its thickness, the quantity of water used, its temperature, etc., there is a difference of corrosive effect even between different parts of the piping in the same building, it being conclusively shown that: (1) The corrosion of hot-water lines gradually decreases with the distance from the boiler. (2) The corrosion is more severe in mains or horizontal lines than in vertical lines conveying either hot or cold water.

Altogether, the records show a remarkable similarity of performance of each of the different kinds of pipe used in the various buildings. Under the most severe service conditions, in a total of 125 buildings, genuine wrought-iron pipe proved to have double the life of soft steel or "wrought pipe," and brass proved to be only slightly better than wrought iron, and certainly not enough better to warrant the many times greater first cost. The average life of hot-water mains of wrought iron is 14 years, and of steel 7 years.

Constructional Steels and Their Heat Treatment. F. C. A. H. LANTSBERRY. (*Journal of the Society of Chemical Industry*, vol. xxxvi, No. 18, p. 983, September 29, 1917.)—Steels are essentially alloys of carbon with iron; silicon and manganese are added in the process of manufacture for well-known reasons. Alloy steels are simply steels to which other elements or an excess of silicon and manganese have been added. Until about twenty years ago alloys were practically never used except for some highly specialized work. Modern requirements, however, demanded properties that plain steels in their condition as then known were incapable of meeting. Resort was then had to the addition of various alloying elements to the steels with the object of improving their mechanical properties. Developments in electrical appliances also demanded the improvement of magnet steels. Further, the introduction of harder steels increased machining difficulties, and improvements in cutting tools followed. At the present time the addition elements for the production of alloy steels are chromium, tungsten, nickel, silicon, manganese, vanadium, molybdenum, cobalt, and titanium.

When originally introduced, alloy steels owed their merit to superior mechanical properties in their untreated state. This superiority was often more imaginary than real. It was soon discovered that by heat-treating these steels still further improvements in their mechanical properties could be effected, and it became apparent to metallurgists that the full value was obtained only after some process of heat-treatment. It is only within the last few years that this knowledge has been extensively applied, and even at the present time much alloy steel is used in its crude state when the cheaper plain steel will serve equally well.

The simple steels used for constructional purposes contain from 0.1 to 0.75 per cent. carbon. In the annealed state their mechanical properties are substantially linear functions of the carbon content and are included between the limits of 16 and 45 tons per square inch yield stress and 20 and 65 tons per square inch ultimate stress, with a contraction in area from 70 to 30 per cent. The elongation being to a large extent a function of the shape and relative dimensions of the test piece, no useful purpose is served by quoting it. By oil-quenching and tempering the mechanical properties of a 0.5 per cent. carbon, steel can be varied between 25 and 87 tons per square inch yield stress and 40 and 102 tons per square inch ultimate stress, with a contraction varying between 50 and 0 per cent. Still higher values, with less contraction, are attainable with higher carbon content. It is obvious, therefore, that the mechanical properties of ordinary carbon steels can be vastly improved by heat-treatment, and in yield and ultimate strength compare favorably with alloy steels. The alloy steels, however, have the advantage of maintaining a high contraction value with high yield and ultimate stresses, and, generally speaking, the higher the contraction the greater will be the resistance to shock.

THE FRANKLIN INSTITUTE

MEMBERS OF THE FRANKLIN INSTITUTE WHO ARE IN THE ACTIVE MILITARY OR NAVAL SERVICE OF THE UNITED STATES GOVERNMENT

Name and rank	Branch of service	Location
Allen, Henry B., 1st Lieut.	Ordnance Dept., U. S. R.	France
Anderson, Geo. L., Colonel	Board of Ordnance & Fortification	Washington
Atherholt, Gordon Meade	Aeronautical Mechanical Engineer, Signal Corps	Washington
Atterbury, W. W., Brig. Gen.	Director-General of Railways	France
Bacon, Raymond Foss, Lt. Col.	Head of Chemical Service Section, U.S.N.A.	France
Barnhart, G. Edw.	Aeronautical Mechanical Engineer, Signal Corps	Fairfield, Ohio
Barr, John H., Major	Ordnance Reserve Corps	Washington
Barrett, C. D., Major	9th Engineers	
Bartow, Edward, Major	U.S.N.A. Sanitary Corps	France
Booz, Horace Corey, Colonel	Railroad Transportation Corps, U.S.N.A.	France
Bostwick, John Vaughan, Capt.	O.R.C., 315th Infantry	Camp Meade
Bunting, C. M., Colonel	E.O.R.C., U.S.A.	France
Cadwalader, Governeur, Major	Ordnance Dept., U.S.R.	
Caldwell, E. W.	Medical Officers' Reserve Corps	
Capps, W. L., Rear Admiral	Chief Constructor, U.S.N., Bureau of Construction and Repair	Washington
Carty, John J., Colonel	Signal Corps, U.S.A.	
Chance, Edwin M., Capt.	Ordnance Dept., U.S.R.	Washington
Clark, Beauvais, Sergeant	108th Field Artillery	Camp Hancock
Clark, E. L., 1st Lieut.	Signal Corps, 401st Telegraph Battalion	Camp Devens
Clark, Theobald F., Capt.	Field Artillery	Fort Sill
Clark, Walton, Jr., Capt.	Field Artillery	Fort Sill
Cornelius, John C., 1st Lieut.	Coast Artillery, U.S.N.A., 13th Company	Sandy Hook
Cottrell, Jas. W., Private	Instruction Section, Ordnance Dept., U.S.A.	Peoria, Ill.
Cowan, Henry B., Sergeant, 1st Class	Co. D., First Telegraph Battalion, Signal Reserve Corps	France
Crampton, George S., Major	Director of Field Hospitals, 28th Div.	Camp Hancock
Cushman, A. S., Lieut. Col.	Ordnance Dept., U.S.N.A.	Frankford Arsenal
Detwiler, Jas. G., 1st Lieut.	Infantry, U.S.R.	Fort Logan H. Roots
Eckert, S. B., Lieut.	Commander 9th Aero Squadron	France
Elliott, Henry M., 1st Lieut.	Ordnance Dept., U.S.R.	Western Cartridge Co.
Emerson, Geo. H., Colonel	In charge of Russian Railway Service Corps	Japan
Felton, Samuel M.	U. S. Director-General of Railways in connection with Expeditionary Force	Chicago

Name and rank	Branch of service	Location
Ferguson, Walter B., Private	21st Co., 154th Depot Brigade	Camp Meade
Fraser, Persifor, Ensign	U.S.N.R.F.	League Island
Gardner, H. A., Senior Lieut.	Naval Flying Corps	Washington
Gfrörer, A. H., 1st Lieut.	Ordnance Dept., U.S.R.	Washington
Gibbons, Joseph E., Private	Co. D., 103rd Engineers	Camp Hancock
Glendinning, Robt. E., Major	Aviation Section, Signal Corps	Overseas
Gribbel, W. G., Captain	Co. A., 30th Engineers, U.S.R. (Gas and Flame)	France
Griest, Thos. S., 1st Lieut.	1st Telegraph Battalion, Signal Corps, U.S.A.	France
Hall, R. T., Rear Admiral	U. S. Navy, Inspector of Machinery	Cramps Shipyard
Hodges, Austin L., Capt.	Ordnance Dept., U.S.R., Experimental Officer on Artillery Ammunition	Frankford Arsenal
Howson, Richard, Sergeant	306th Ambulance Corps	Camp Meade
Ives, H. E., Captain	Signal Corps, U.S.A.	Washington
Jones, Jonathan, Captain	E.O.R.C., 23rd Engineers	Camp Laurel
Kennedy, M. C., Colonel	Deputy Director General of Transportation	France
Kent, S. Leonard, Jr., 2nd Lieut.	5th Engineers	Camp Lee
Kingsbury, E. F., 1st Lieut.	Aviation Section, S.O.R.C., Dept. of Science and Research	Washington
LeBoutillier, H. W., Private	Unit No. 10, Pennsylvania Hospital	France
Lichtenberg, Chester, 1st Lieut.	Engineer Reserve Corps, U.S.A.	Washington
Longstreth, Chas., Lt. Commander	U.S.N.R.F.	Philadelphia
McCoy, John F.	Aviation Section, Signal Corps	Princeton
MacLean, Malcolm R., 1st Lieut.	Co. 9, Officers' Reserve Corps	
Martin, Thos. S., 1st Lieut.	Ordnance Dept., U.S.R.	Washington
Masters, Frank M., Major	Ordnance Dept., U.S.R.	Washington
Maxfield, H. H., Lieut. Col.	19th Railway Engineers, U.S.N.A.	
Mershon, Ralph D., Major	E.O.R.C., U.S.A.	New York
Miller, Fred. J., Major	Ordnance Reserve Corps	Centre Bridge, Penna.
Owens, Major R. B.	Signal Corps	France
Parrish, T. R., 1st Lieut.	Signal Corps	Washington
Reber, Samuel, Colonel	Signal Corps, U.S.A.	New York
Richardson, Chas. E., 1st Lieut.	30th Engineers, U.S.R. (Gas and Flame)	France
Spackman, Henry S., Major	Engineer Officers' Reserve Corps	France
Spruance, W. C., Jr., Lt. Col.	Ordnance Dept., National Army	Chevy Chase, Md.
Squier, Geo. O., Major General	Chief Signal Officer, U.S.A.	
Stanford, H. R., Civil Engineer	U. S. Navy	Boston
Thomas, Geo. C., Jr., Captain	Aero Service Squadron 96, Aviation Section, Signal Corps	France
Tilghman, B. C., Captain	A.D.C., 28th Div. Headquarters, U.S.A.	
Vogleson, J. A., Major	Sanitary Corps (Surgeon General's Dept.)	Fort Oglethorpe
Wagner, Fred. H., Major	Ordnance Reserve Corps, Nitrate Division	Washington
Wagner, Fred. H., Jr. Sergeant	Co. E., 304th Engineers	Camp Meade
Wetherill, W. C., Ensign	U. S. Navy	
Wood, Edw. R., Jr., Captain	18th Field Artillery, U.S.N.A.	El Paso, Texas

Name and rank	Branch of service	Location
Worrell, Howard Sellers	3rd Officers' Training Camp	Fortress Monroe
Wyckoff, A. B., Lieut.	U. S. Navy	Ontario, Cal.
Yale, A. W. Major	Medical Reserve Corps, Gas Division	Camp Kearney
Yorke, George M., Major	Signal Corps, U.S.R.	New York

MEMBERS DOING CIVILIAN WORK FOR THE UNITED STATES GOVERNMENT

Name	Appointment	Location
Anderson, Robt. J.	Engineer of Tests of Ordnance, War Dept., U.S.A.	Brier Hill Steel Co.
Balls, William H.	Ships Draughtsman	Phila. Navy Yard
Bancroft, Joseph	Secretary, Local Board No. 1	Wilmington
Baskerville, Charles	Working with Bureau of Mines, Ordnance Dept., (Gas Warfare, Shells, etc.)	New York
Bodine, Samuel T.	Vice-Chairman, District Exemption Board, No. 1, Eastern Judicial District of Penna.	Philadelphia
Burnham, George, Jr.	Dept. of Civilian Service and Relief, Public Safety Committee of Pennsylvania	Philadelphia
Charles, Bernard S.	Ordnance Inspector, U. S. Navy	Allentown, Pa.
Comey, Arthur M.	Chairman, Sub-Committee on Explosives, Chemistry Committee, National Research Council	Chester, Pa.
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Cope, Thomas D.	National Research Council	Washington
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Halberstadt, Baird	Federal Fuel Administrator for Schuylkill Co., Penna.	Pottsville
Hyde, Edward P.	National Research Council, Sub-Committee on Monocular vs. Binocular Field-Glasses (Chairman).	Cleveland
Insull, Samuel	Chairman, Illinois State Council of Defense	Chicago
Kennelly, A. E.	Conducting special course in radio-engineering for the U. S. Signal Corps, in conjunction with Prof. E. C. Chaffee	Harvard Univ.
Lloyd, E. W.	Asst. Secretary, Illinois State Council of Defense	Chicago
Lucke, C. E.	Civilian Director, U. S. Navy Gas Engine School	Columbia Univ.
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Name	Appointment	Location
Milne, David	Treasurer, American Red Cross General Hospital No. 1	Philadelphia
Morris, Effingham B.	Treasurer, Committee of Public Safety, State of Pennsylvania	Philadelphia
Nichols, Carroll, B.	Fuel Administration	Washington
Nichols, Wm. H.	Committee on Chemicals, Advisory Council of National Defense, Consulting Chemist, Bureau of Mines	New York
Penrose, R. A. F., Jr.	Member of Geology Committee of the National Research Council	Philadelphia
Rautenstrauch, Walter	Committee of the National Research Council	New York
Richards, Joseph W.	Member of Naval Consulting Board	So. Bethlehem, Penn.
Robins, Thomas	Member and Secretary of the Naval Consulting Board	New York
Sperry, Elmer A.	Member of Naval Consulting Board	Brooklyn, N.Y.
Sprague, Frank J.	Member of Naval Consulting Board, Chairman, Committee on Electricity and Shipbuilding	
Stradling, George F.	Recruiting for Aviation Section, S.O.R.C.	Philadelphia
Talbot, Henry P.	Member of Advisory Board, Bureau of Mines, (Gas Defense)	Cambridge, Mass.
Thomson, Elihu	National Research Council in cooperation with Council of National Defense	Swampscott, Mass.

Please send additional information and corrections to the Secretary.

(Proceedings of the Stated Meeting held Wednesday, February 20, 1918.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 20, 1918.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 10.

Reports of progress were presented by the Committee on Science and the Arts and the Committee on Library. The standing committees for the year 1918–'19 were announced.

The paper of the evening, entitled "Dyestuffs," was presented by Louis Joseph Mátos, Ph.D., Technical Chemist and Chemical Engineer, The Cassella Color Company, New York City. The speaker gave a brief account of the development of dyeing and color-making. A description was also given of the sources, production, and applications of dyestuffs, both natural and of coal-tar origin, as well as the development of the various related industries in this country since the beginning of the war. Reference was made to the present opportunities for closer relations between the engineer and chemist in the field of inorganic chemistry and to the training of chemists for such work. The subject was illustrated by lantern slides.

After a brief discussion, the thanks of the meeting were extended to the speaker.

Adjourned.

GEORGE A. HOADLEY,
Acting Secretary.

STANDING COMMITTEES, 1918.

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COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, February 6, 1918.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 6, 1918.

MR. BENJAMIN FRANKLIN, *Chairman pro tem.*

The following reports were presented for first reading:

No. 2656.—Automatic Operation of Water Gas Sets.
No. 2690.—Havard Coal Meter.

The following report was presented for final action:

No. 2704.—Sweetland Filter Press.
Recommended that the John Scott Legacy Medal and Premium be awarded to Ernest J. Sweetland, of Upper Montclair, N. J.

GEORGE A. HOADLEY,
Acting Secretary.

SECTIONS.

Section of Physics and Chemistry.—A joint meeting of the Section and the Philadelphia Section of the Illuminating Engineering Society and the Physics Club of Philadelphia was held in the Hall of the Institute on Thursday evening, January 10, 1918, at 8 o'clock. Dr. George A. Hoadley introduced Mr. Walton Forstall as presiding officer of the evening. The minutes of the previous meeting were read and approved.

Herbert E. Ives, Ph.D., Physicist of the United Gas Improvement Company, Philadelphia, delivered an address on "The Physics of the Welsbach Mantle." The relationship between the chemical composition, the temperature, and the luminous efficiency of a mantle were discussed, with special reference to mantles composed of oxides of the rare earths, or of mixtures of these oxides. A report was made concerning the relative proportion of radiated, convected, and conducted heat produced by the consumption of energy in a gas light. The address was illustrated with experiments and lantern slides.

The paper was discussed by Prof. Monroe B. Snyder, Messrs. Forstall, Henderson, and Gulbrandson, and Doctors Hoadley and Ives. On motion of Dr. Walton Clark, a vote of thanks was extended to Doctor Ives. After adjournment, the audience was permitted to inspect an exhibit of raw materials, finished mantles, and mantle accessories shown by the Welsbach Company.

JOSEPH S. HEPBURN,
Secretary.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, January 24, 1918, at 8 o'clock, with Dr. Harry F. Keller in the chair. The minutes of the previous meeting were approved as read.

Lucius Polk Brown, Director of the Bureau of Food and Drugs, Department of Health, New York City, N. Y., delivered a lecture on "Food Wastes—Some Causes and Remedies." The course of foodstuffs was traced from the producer to the consumer; the wastes, which occur in the producer's hands, during transit, during distribution in the city, in the household and restaurant, and in trade channels, were described, and methods for their elimination were suggested.

The paper was discussed by Professor Lawall, Dr. Carl. Hering, Mr. C. S. Brinton, and others. On motion of Dr. George A. Hoadley, a vote of thanks was extended to Mr. Brown. The meeting then adjourned.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, January 31, 1918, at 8 o'clock, with Dr. Henry H. Donaldson in the chair. The minutes of the previous meeting were read and approved.

Ross G. Harrison, M.D., Ph. D., of Yale University, New Haven, Conn., delivered a lecture on "Animal Transplantation." The history of animal transplantation was traced, and the applications of grafting in modern surgery were reviewed, with special reference to the replacement of lost parts and the assistance of wound healing. A detailed account was then given of the use of grafting in embryological researches on problems of development. The lecture concluded with a description of the growth *in vitro* of isolated living tissue. The lecture was illustrated with lantern slides.

The paper was discussed by Doctors Eldridge, Donaldson, and Harrison. A vote of thanks was extended to Doctor Harrison, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Electrical Section.—A joint meeting of the Section and the Philadelphia Section of the American Institute of Electrical Engineers was held in the Hall of the Institute on Thursday evening, February 7, 1918, at 8 o'clock. The meeting was presided over by Mr. N. Hayward, chairman of the A. I. E. E. The lecture was delivered by Edwin F. Northrup, Ph.D., of the Palmer Physical Laboratory, Princeton University, and his subject was "The Application of Oscillatory Currents to Heating and Electric Furnace Practice."

Doctor Northrup's remarks were limited to the induction type of furnace, and he gave a demonstration at the blackboard of the theory and the formulæ involved in their design. He then described the theory of oscillatory currents as obtained from condensers. Such currents, used in connection with transformers, may cause large quantities of heat to be generated, which can be used both experimentally and commercially in the reduction of metals. It was shown that the best results are obtained by using frequencies of 10,000 to 25,000 cycles per second.

He then proceeded to describe a new form of furnace which had been designed by him. The condenser consisted of glass and brass plates, the former being used because cheaper than mica. The crucible consisted of nicrome or graphite, depending upon the nature of the contents, and the furnace possessed several novel features and contained no iron in its construction. As only one furnace had been completed, and it but recently, no exhaustive tests had been made, but with an 18-kilowatt furnace an efficiency of 55 per cent. had been attained, and experiments indicated that this should be increased to 70 per cent. or more. The principal loss occurs in the air-gap, while the loss in the condenser is small if properly constructed.

After considerable discussion the meeting adjourned.

H. CALVERT,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, February 13, 1918.)

LIFE.

MR. THOMAS BILYEU, Mechanical Engineer, Hillsboro, Ore.

RESIDENT.

MR. GEORGE A. BUCKLEY, Real Estate, Ardmore, Pa.

MR. WILLIAM STEELL JACKSON, Patent Attorney, 1001 Chestnut Street, Philadelphia, Pa.

DR. WALTER L. PYLE, Physician, 1931 Chestnut Street, Philadelphia, Pa.

NON-RESIDENT.

DR. M. C. BURT, Chemist, Atlas Powder Company, and for mail, 231 West Broad Street, Tamaqua, Pa.

MR. JESSE COATES, National Research Council, 1023 Sixteenth Street, N. W., Washington, D. C.

DR. WALTER O. SNELLING, Research Chemist, 208 North Fifth Street, Allentown, Pa.

ASSOCIATE.

MR. HERMAN EILBERG, Chemist, 2411 South Fourth Street, Philadelphia, Pa.

MR. ANTHONY DE H. HOADLEY, Student, 518 Walnut Lane, Swarthmore, Pa.

MR. CHARLES H. MASLAND, 2D, Chemical Engineer, 1202 Stratford Avenue, Melrose Park, Pa.

MR. JOSEPH VALASEK, Physicist, 2069 Park Road, Washington, D. C.

CHANGES OF ADDRESS.

PROF. WILLIAM H. BALLS, 1422 Snyder Avenue, Philadelphia, Pa.

MR. C. E. BENNETT, The Kenilworth Apartments, Ponce de Leon Avenue, Atlanta, Ga.

MR. LEON C. BIBBER, P. O. Box 331, Newport News, Va.
MR. R. BURDETTE DALE, 31 West Tenth Street, Erie, Pa.
LIEUT. S. B. ECKERT, Commander 9th Aero Squadron, American Expeditionary Force, via New York.
DR. H. FOERSTERLING, care of The Abor Farm, Jamesburg, N. J.
LIEUT. E. F. KINGSBURY, 1023 Sixteenth Street, N. W., Washington, D. C.
MR. WM. J. MCGURTY, 3904 Brookline Avenue, Arlington, Md.
COL. SAMUEL REBER, Signal Office, Eastern Department, Maritime Building, 8–10 Bridge Street, New York City, N. Y.
LIEUT. COL. W. C. SPRUANCE, JR., 6400 Rockville Road, Chevy Chase, Md.
MR. L. H. THULLEN, 211 South Jefferson Avenue, Grand Rapids, Mich.
MR. CHARLES S. VADNER, Box 539, Reno, Nev.
MAJOR JOHN A. VOGLESON, Sanitary Corps, N. A., Camp Greenleaf, Fort Oglethorpe, Ga.
MR. L. D. VORCE, care of Canadian Salt Company, Ltd., Windsor, Ontario.
MAJOR GEORGE M. YORKE, 195 Broadway, New York City, N. Y.

NECROLOGY.

George Edward Bartol, a life member of The Franklin Institute, a founder and for twenty-six years president of the Philadelphia Bourse, died November 13, ultimo, at the University Hospital, in this city, after an illness of several weeks. He was born in Philadelphia, January 29, 1858, the son of Barnabas H. Bartol, a resident of Philadelphia after his removal from Freeport, Maine, in 1847. To Mr. Barnabas H. Bartol the Institute is indebted for the foundation of the Bartol Scholarship in the Department of Mechanical Drawing of the Institute's night schools.

At the age of 16 young Bartol, after going through the courses of a private school, was given the experience of a nine months' cruise before the mast in a sailing vessel connected with his father's sugar refining business, the Grocers' Sugar Company, and on his return was placed as engineer's apprentice in the refinery. In a short time he became assistant superintendent of the refinery, and in 1881, in his twenty-third year, came into its complete control. Six years later, in 1887, he withdrew from this occupation to engage in the foreign commission business, making his connections in Great Britain, Belgium, and Germany, and during his stay abroad took time to supplement his early education by attending courses of lectures at Heidelberg and in Brussels.

His experiences in the prosecution of his merchandising and commission business brought Mr. Bartol to a realization of the advantages of unified effort in the development of commercial possibilities, as indicated by the activities of the bourse organizations in the chief European cities, and, strongly imbued with public spirit as he was, he was impelled to take the lead in the establishment of a similar institution in Philadelphia. Through his efforts in this direction the Philadelphia Bourse was founded under his presidency in 1891, and from then on that organization claimed such constantly increasing measure of his time and attention that, although at one

time he had become the largest exporter of grain in Philadelphia, he gave up his business in 1897 and devoted himself entirely to the activities of the Bourse and to the advancement of the mercantile and maritime interests of his native city.

Mr. Bartol was a leader in movements for the development of the port of Philadelphia and in furthering unity of action and coöperative effort among the trades interests of the city. Within the last two years he organized and directed the "Via Philadelphia Movement," in which all the leading business bodies of the city are affiliated, and was a leading spirit in the reorganization and improvement of the Philadelphia Belt Line Railroad. He was also active in the organization of the Joint Committee on Reasonable Regulation of Railroads, which initiated a national campaign for a more equitable and unified system of railroad regulation. The widely reputed "Philadelphia Plan" for regulation through regional connections was prepared chiefly by him.

Mr. Bartol was a recognized authority on waterway as well as railroad transportation, and was the first president of the National Rivers and Harbors Congress. He was a member of the Inland Water Transportation Committee of the Council of National Defence, and shortly before his death he completed for the Government a survey of the possibilities of the canals and other inland waterways of the eastern United States for immediate use in relieving the railroads of part of their great burden of war transportation. Mr. Bartol was a director of the Girard National Bank, the Western New York and Pennsylvania Railroad, the Dexter Portland Cement Company, the C. Howard Hunt Pen Company, and the Philadelphia Belt Line Railroad Company, and was a member of the Union League, the Corinthian Yacht Club, and of the Second Presbyterian Church. He is survived by his wife, Jane Newman Grier Bartol, two daughters, and two sons, the latter, George E. Bartol, Jr., and J. Grier Bartol, having taken up army service at the Officers' Training Camp at Fort Oglethorpe, and having since been awarded commissions in the Aviation Corps and the Artillery.

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BOOK NOTICES.

TREATISE ON APPLIED ANALYTICAL CHEMISTRY: METHODS AND STANDARDS FOR THE CHEMICAL ANALYSIS OF THE PRINCIPAL INDUSTRIAL AND FOOD PRODUCTS, by Prof. Vittorio Villavecchia, with collaborators. Translated by Thomas H. Pope, B.S., A.C.G.I., F.I.C., University of Birmingham. Philadelphia, P. Blakiston's Son & Company, 1918, vol. 1, 470 pages, contents and index, illustrations, 8vo. Price, $6.

The name and work of Professor Villavecchia have long been known to those engaged in commercial analysis. As director of the laboratories of the Italian Customs service, he has had an extended experience with testing the raw materials and manufactured articles of commerce. The work is to appear in two volumes. The present volume covers the subjects: Waters, Chemical Products (general commercial inorganic and organic substances), Fertilizers, Cement Materials, Metals and Alloys, Fuels, Coal-tar and Products, Mineral Oils and Derivatives, Fats and Waxes, Industrial Treatment of Fatty Substances.

All these topics are treated carefully and clearly, and there is a great deal of information given in a compact form. The article on Metals and Alloys covers about one hundred and thirty pages and gives a large amount of interesting information concerning the many special alloys that have of late years been introduced to meet the necessities of high-speed tools, motor cars, and flying machines.

The work is well translated, well printed on excellent paper; indeed, in view of the cost and scarcity of good paper it is a question whether a cheaper grade might not have answered. It would not have made so handsome a book, but would have been as serviceable to the laboratory.

The American reviewer will be especially interested in the extent to which the author and translator have utilized American work, that has been so fertile of late years in all the fields covered by the book. He will be much disappointed that only one reference to an American periodical is discoverable, and that to an article twenty-two years old, with both the name of the author and the page reference inexact.

HENRY LEFFMANN.

PUBLICATIONS RECEIVED.

Agricultural Bacteriology: A Study of the Relation of Germ Life to the Farm, with Laboratory Experiments for Students. By. H. W. Conn, Ph.D. Third edition, revised by Harold Joel Conn. 357 pages, illustrations, 12mo. Philadelphia, P. Blakiston's Son & Co., 1918. Price, $2.

U. S. Coast and Geodetic Survey: Terrestrial Magnetism: United States Magnetic Tables and Magnetic Charts for 1915, by Daniel L. Hazard, chief, Division of Terrestrial Magnetism. 256 pages, maps, 8vo. Washington, Government Printing Office, 1917.

North Carolina Geological and Economic Survey: Biennial Report of the State Geologist, 1915–16. 202 pages, illustrations, quarto. Bulletin No. 27, altitudes in North Carolina, compiled by the North Carolina Geological and Economic Survey. 124 pages, quarto. Raleigh, State Printers, 1917.

U. S. Bureau of Mines: Bulletin 148, Petroleum Technology 37, Methods for Increasing the Recovery from Oil Sands, by J. O. Lewis. 128 pages, illustrations, 8vo. Bulletin 153, The Mining Industry in the Territory of Alaska during the Calendar Year 1916, by Sumner S. Smith, U. S. Mine Inspector. 89 pages, plate, 8vo. Technical Paper 174, Suggestions for the Safe Operation of Gasoline Engines in Mines, by R. H. Kudlich and Edwin Higgins. 19 pages, illustrations, 8vo. Technical Paper 133, Directions for Sampling Coal for Shipment or Delivery, by George S. Pope. 15 pages, plate, 8vo. Monthly Statement of Coal-mine Fatalities in the United States, October, 1917, compiled by Albert H. Fay. 31 pages, 8vo. Washington, Government Printing Office, 1917.

U. S. Bureau of Foreign and Domestic Commerce: Annual Report of the chief for the Fiscal Year Ended June 30, 1917. 77 pages, 8vo. Washington, Government Printing Office, 1917.

Cultivation of Medicinal Plants in the United States. R. P. FISCHELIS. (*The Catalyst*, vol. 2, No. 10, p. 3, December, 1917.)—In the strictly pharmaceutical field, the shortage of crude drugs has been felt more or less keenly since 1914, and much misinformation and little information of value have been circulated on the subject. Stocks of many crude drugs have been exhausted and the cultivation of medicinal plants has not yet assumed any great proportions in the United States. Those drugs which were obtained from

Europe were not cultivated, but grew wild there. It was therefore a simple matter to have them gathered and prepared for market at comparatively slight cost. The cultivation of medicinal plants in the United States requires expert labor, the production of artificial conditions of soil and moisture in order to provide as nearly as possible the conditions under which the plants grow in their native habitat, and considerable investment of money.

Drug plants have been raised on an experimental scale by the Government and in the drug gardens of various colleges, but it is a very different undertaking to raise them on a commercial scale. American growers of crude drugs were confronted with the necessity of increasing the value of the plants in order to overcome the high cost of cultivation. It was soon found that cross-pollination would not produce plants containing more active constituent than they do normally, but by careful selection of seed it has been possible to increase the amount of active constituent in such plants as belladonna, digitalis, etc., to three or four times what the Pharmacopœia requires. Furthermore, advanced methods of harvesting these plants have made it possible to secure three or four harvestings in one season, whereas in former years one or two was the limit.

Low Visibility Paints. ANON. (*Graphite,* vol. 20, No. 2, p. 4283, February, 1918.)—Low visibility and service are important points when choosing a paint. Ornamentation is not always the first consideration. It may be more important to soften the lines and blend the color into the horizon. For instance, it may be important not to emphasize a house in the woods, but to make its lines blend with the trees that surround it. Certainly in the case of smokestacks, gas holders, etc., it is important to blend them with the horizon as much as possible, as it is not always desirable in a town or city that they should be conspicuous. At one time the American naval vessels were all painted white. The British Navy during the bombardment of Alexandria had its vessels painted black, with yellow smokestacks. This gave a splendid mark to the enemy gunners.

About the year 1902 these ideas began to change. Service and low visibility became matters of importance. The British Navy authorities then ordered that the warships be painted a horizon gray, and civilians thought the change offended the art sense, etc. It did, but art is not the main point in the dress of a warship. At the great battle off the coast of Jutland it was reported that many of the German warships succeeded in getting away from the combined British fleets because of " low visibility." The German ships were painted a " dirty gray " so that they might blend with misty weather and with the horizon. Commercial ships are now also painted in this manner so as to escape submarines, and we have seen some ships on which wavy lines of gray, green, or other colors are used.

CURRENT TOPICS

Oil Shales Reserved for the Navy. ANON. (*U. S. Geological Survey Press Bulletin*, No. 349, December, 1917.)—In the annual report of the Director of the Geological Survey, Department of the Interior, just made public, attention is called to the creation of two naval oil reserves in Colorado and Utah. The Survey has been investigating the oil shales of the United States that give the most promise of yielding a commercial supply of oil, and has explored large areas in Colorado and Utah that contain immence deposits of such shales, some of which carry 30 to 50 gallons of oil to the ton. This potential resource is estimated by the Survey in terms of billions of barrels of oil, which it is believed can be economically extracted from the shales, possibly in competition with the petroleum at present prices. It is therefore of special interest to note that during the last year two oil-shale reserves were created for the use of the Navy, one of 45,440 acres in Colorado and one of 86,584 acres in Utah.

General classification of oil-shale land was continued by the Survey during the year, the work covering large areas. Geologic examination of the oil-shale region of the West has shown that the oil shales in Utah and Colorado contain enormous quantities of petroleum. They also contain a considerable percentage of nitrogen, aggregating a vast supply, which can be recovered as a by-product in the refining of the shale and used either as a fertilizer or in the manufacture of explosives.

History of the Manhattan Railway Company's System. F. W. GARDINER and S. JOHANNESSON. (*Proceedings of the American Society of Civil Engineers*, vol. 43, No. 10, p. 2043, December, 1917.)—Elevated railroad construction in New York City was commenced on July 1, 1867, when "The West Side and Yonkers Railway Company" started to erect an experimental section on Greenwich Street, between Battery Place and Cortlandt Street. This section was completed on July 2, 1868, and was a single-track railroad. The line was extended as a single-track road through Greenwich Street and Ninth Avenue to Thirtieth Street during the following two years, and was opened for traffic on February 14, 1870. The structure was on the east side of the street through Greenwich Street and on the west side through Ninth Avenue. The trains were operated by an endless chain, driven by stationary engines below the surface of the street, at Cortlandt, Franklin, Bank, and Twenty-second Streets. This method of traction did not prove successful, and traffic was abandoned in November, 1870, but was resumed

again on April 20, 1871, using a dummy engine, the "Pioneer," weighing five tons and drawing three cars.

In the fall of 1871 the bondholders of the company organized under the General Railroad Laws as "The New York Elevated Railroad Company." In October, 1872, the company announced that it would receive passengers at Morris, Dey, Canal, Twelfth, and Twenty-ninth Streets. During the following years the line was gradually extended northward on Ninth Avenue—in 1873 to Thirty-fourth Street, in 1875 to Forty-second Street, and in 1876 to Fifty-ninth Street. In 1877 a double-track extension was built to South Ferry, and during 1878 a double track was completed and opened for traffic over the whole line. At the same time the rolling stock was increased, consisting, in 1874, of 10 cars and 6 engines and, in 1876, of 21 cars and 15 engines. The original structure on the east side of Greenwich Street and on the west side of Ninth Avenue, between Battery Place and Fifty-ninth Street, was torn down in sections and replaced by a new structure, which was completed in May, 1880.

In October, 1877, the New York Elevated Railroad Company commenced the construction of the Third Avenue Line, and opened it for traffic on August 26, 1878, between South Ferry and Forty-second Street. The line was extended and opened for traffic to 129th Street before the end of the year. The Forty-second Street branch to Grand Central Station was also opened in August, 1878; the City Hall branch, from Chatham Square to City Hall, was completed in March, 1879, and the Thirty-fourth Street branch to the East River was opened in July, 1880.

Another company, the Metropolitan Railway Company, formerly called the Gilbert Elevated Railway Company, in the spring of 1876 commenced to construct what is now called the Sixth Avenue Line, between Morris Street and Fifty-ninth Street, but became involved in legal difficulties, and the road was not opened until June, 1878. The same company opened the line through Fifty-third Street from Sixth to Ninth Avenues and the line in Ninth and Eighth Avenues from Fifty-ninth to 155th Street in 1878. The Metropolitan Elevated Railway Company also constructed an east-side line from Chatham Square through Division Street, Allen Street, and First Avenue to Nineteenth Street, which was opened in September, 1879; the remainder of the line—which is now the Second Avenue Line—to 129th Street, was opened in 1880.

In May, 1879, the New York Elevated Railroad Company and the Metropolitan Elevated Railway Company were leased to the Manhattan Railway Company (first organized in November, 1875) for 999 years, "in order, by means of one management, to avoid dangers of level crossings and also to perfect the system of rapid transit." This was known at the time as the Tripartite Agreement of May 20, 1879. The authorized rates of fares at that time were 10 cents for any distance of less than five miles, and not to exceed 15 cents for a through passage between the Battery and the Harlem

River, except on "Commission Trains," which ran between 5.20 and 7.20 A.M. and between 5 and 7 P.M., when the corresponding rates were 5 and 7 cents. The 5-cent fare was introduced for all hours on all lines on November 1, 1886. It is interesting to note that as early as January 20, 1879, the collection of tickets by the conductors was abolished, the passengers on and after that date depositing their tickets in the ticket boxes provided at the exit gates, on leaving the trains. This was changed on June 21, 1880, to the present method of depositing the tickets in cancelling boxes at the entrance.

Another elevated railroad company, the Suburban Rapid Transit Company, was originally chartered in October, 1880, but did not commence construction until November, 1883, when the work on the foundations for the Harlem River Bridge at 129th Street and Second Avenue was started. The road was opened for traffic between 128th and 143d Streets in 1886, extended to 166th Street and Third Avenue in 1887, to 169th Street in 1888, and to 177th Street in 1891. The line from 177th Street to Fordham Road was opened in July, 1901, and from Fordham Road to Bronx Park in May, 1902.

On June 4, 1891, the Manhattan Railway Company assumed control of the Suburban Rapid Transit Company, and from that date, therefore, was in possession of all the elevated lines in Manhattan and The Bronx.

During 1899 to 1901 the whole system was equipped for electric traction, and since June 25, 1903, all trains have been run by electric motive power.

On April 1, 1903, the Manhattan Railway Company leased the system to the Interborough Rapid Transit Company, which since then has operated the lines.

Pig Iron from Scrap Steel. ANON. (*Mining and Scientific Press*, vol. 115, No. 26, p. 936, December 29, 1917.)—The electric furnace has made possible what may be regarded as almost a revolution in the steel industry. It is the conversion of scrap steel or iron back into pig iron. What may be called "synthetic pig iron" is now a commercial product; in other words, the original constituents of pig iron are being made to reunite in the condition originally assumed. This unusual achievement is another evidence of the adaptability of electrical energy to the production of results impossible by any other means. The new process is being applied commercially in a large electric-steel plant in the eastern part of the United States, high-grade or low-phosphorus pig iron being made directly from ordinary scrap steel. Not only is pig iron being produced in large quantities, but wash-metal and iron and steel castings are made in the same furnaces. The pig iron sells in the open market as a competitor with regular low-phosphorus blast-furnace iron, the wash-metal goes to crucible-steel makers, and the iron castings are sold to near-by users, or else are used by the company in its rolling mill.

The idea is not new, but this is the first record of its commercial

exploitation in the United States. Late in 1912, Horace W. Lash, of the Garrett-Cromwell Engineering Company, of Cleveland, organized a corporation for the purpose of converting scrap steel and iron into pig iron in an electric furnace on the Pacific coast. Pig iron being expensive in that part of the country, and the fact that it could be made by this process without the use of coke, charcoal, or coal, which are not cheaply available there, were the impelling reasons. It is not known that the company carried out its plans, but it is understood that Robert Trumbull, an engineer at one time identified with Heroult in his efforts to introduce his electric furnace in America, is now producing pig iron from scrap in an electric furnace in Canada.

The Eastern concern that has been successfully operating, as stated above, is known as the Sweetser-Bainbridge Metal Alloy Corporation of Watervliet, N. Y. For several months it has been producing from a Ludlum electric furnace. About 50 tons per day is the present output from two 5-ton furnaces.

Water Resources of Hawaii. ANON. (*U. S. Geological Survey Press Bulletin,* No. 341, November, 1917.)—The rainfall on the Hawaiian Islands varies from a few inches to nearly 400 inches a year, and, as much of the fertile area is made to produce through irrigation, the study of the water supply of the islands is a matter of great importance. It is stated that the critical period is approaching in Hawaiian agriculture, and that the time has come in the utilization of water when it becomes necessary to have all the information possible regarding its available sources.

Among the principal crops of the islands are sugar, rice, and taro; many fine pineapples also are grown. Sugar is by far the most important product, and large areas planted in cane depend entirely on irrigation. Some of the lands are naturally adapted to the growing of rice, but require a certain quantity of water, varying in amount with the stage of the crop. Taro is also an important crop, furnishing the staple food for a considerable part of the population; it requires a continual application of water during its growth. Taro is a large plant which yields a root tasting somewhat like an Irish potato. It is grown to a considerable extent in the United States as an ornamental plant and is popularly known as elephant's ear.

In making plans for power, irrigation, municipal water supply, and other projects involving the use of water from any stream it is necessary to have data from which the total flow of the stream and its variation from day to day throughout the year can be obtained. Since November, 1909, a study of the streams of Hawaii has been carried on at gauging stations maintained by the United States Geological Survey, Department of the Interior, in coöperation with the Territory of Hawaii, and Water-Supply Paper 430, "Surface Water Supply of Hawaii," just issued by the Geological Survey, Department of the Interior, gives the results of this study during the

period from July 1, 1913, to June 30, 1915. It contains a list of the gauging stations maintained on the islands, estimates of the daily and monthly discharge of the streams, and the results of studies of rainfall at many points. Water-Supply Paper 318 gives the results of water-resource investigations in Hawaii for the years 1909–1911, Water-Supply Paper 336 the work for 1912, and 373 the work for 1913.

These reports will be valuable to engineers and others engaged in developing the water resources of the islands. Water-Supply Papers 318 and 373 are no longer available for free distribution, but may be purchased from the Superintendent of Documents, Washington, D. C., for 50 cents and 40 cents, respectively. Copies of Nos. 336 and 430 may be obtained without cost on application to the Director, United States Geological Survey, Washington, D. C.

Color from the Physical Point of View. H. C. RICHARDS. (*Proceedings of the Illuminating Engineering Society,* October 11, 1917.)—The color of light may be expressed in terms of its hue, brightness, and saturation; or it may be defined by the relative amounts of three standard colors, as red, green, and blue, which must be added to produce the same impression on the eye. But these are more or less subjective definitions. From a physical point of view the character of a light (*i.e.,* its color) is determined by the distribution of energy among the different wave-lengths in the spectrum. The translation of this information into terms of color sensation is effected by the study of the effect of light of various wave-lengths in producing the fundamental color sensations.

It should be noticed, however, that the converse is not true; *i.e.,* it is not possible to infer without ambiguity the constitution of a light from observations of its color, since various combinations of spectral constituents will yield the same color sensation. There is here a contrast between the sister sciences of optics and acoustics. The characteristics which distinguish sounds—pitch, intensity, and quality—correspond completely to the three physical properties of a wave-length, amplitude and form a complexity, while in optics the coördination of the properties of hue, brightness, and saturation to the corresponding physical properties is imperfect.

Two classes of illuminants are included in the physical laws determining the color of a light source: those having discontinuous spectra and those having continuous spectra. To the former belong luminous vapors, to the latter incandescent solids and liquids. The classes differ not only in their physical structure but also in the method by which the luminosity is produced; for, while continuous spectra are produced by heat alone, the production of a discontinuous spectrum requires for the most part electrical or chemical action, though in some cases heat is used to stimulate such action.

Sources giving discontinuous or bright line spectra furnish us with the most brilliant and varied color lights. These are produced

by salts volatilized by a flame or by the electric discharge through rarefied gases. Here we have all degrees of complexity, from light of but one wave-length, as in the yellow of sodium or the green of thallium, to that of mercury vapor, where there are half a dozen constituents, and so on to more complex cases, as that of iron with thousands of lines. When the wave-lengths present are predominantly in one portion of the spectrum, the light will be more or less richly colored, as for instance in the brilliant red of the strontium flame or of the neon vacuum tube. When the energy is more or less uniformly distributed through the spectrum the light becomes whitish in character, as with the Moore carbon dioxide tube or even the mercury vapor light. By far the greater number of illuminants belong to the class of those having continuous spectra, and among these we must include our most important or standard light—that of the sun. In these the prominent part is played by temperature. It is a familiar phenomenon that as the temperature of a body is raised it changes in color as the body becomes successively red hot, yellow hot, and white hot.

The light of a source is usually modified by transmitting it through a selectively absorbing medium, such as colored glass. This subtracts from the light its different constituents in varying proportion so as to modify its spectral quality. By this means one light source may be made to produce the same effect as another, as has been done in the last few years with the " daylight glass " shade, which modifies the light of a tungsten bulb to approximate the quality of daylight. Another but less usual method of modifying the color of a light is by selective reflection. Instances of this are to be found in the gilding of the reflectors of automobile headlamps to produce a yellower beam, in the effect of reflection from the walls in interior lighting, and in summer in the slightly green tinge of daylight from light reflected by foliage. Again, a light of given quality may be produced by combining sources of different kinds. This method has also been used to produce artificial daylight. It is also the basis of some processes of color photography, where any color is imitated by the addition in various proportions of red, green, and blue lights.

Simplicity of Fastening Design. ANON. (*Machinery*, vol. 24, No. 4, p. 304, December, 1917.)—Machine designers often miss a golden opportunity for saving in the cost of manufacture of details by being too careful in proportioning the fastening details. It is not uncommon to find a machine well designed in all its essential mechanism which requires a large variety of screws, studs, and bolts to hold the parts together. The screws may have been carefully selected with due consideration of their respective stresses and functions, but that scrupulous care may have resulted in carrying out the design with too little regard for the cost of production. It might have been better, from the manufacturing standpoint, to

have made some of the screws larger than actually required for strength, or to have used two small screws in place of one large one, so that as many as possible could be of one size and type. Thus time would be saved in drilling and tapping, and less variety of screws would be required in stock.

An 18-inch engine lathe is being built in which the fastening screws, with a few exceptions, are 5/8-inch diameter and of the same length. In some places, of course, a 5/8-inch screw is too large, and in others it is necessary to use two screws instead of one. Some holes have to be drilled and tapped deeper than is really necessary; but the gain outweighs the loss. By standardizing to one diameter and length of screw only, much time is saved in machining and assembling, and the job of making and keeping stock is simplified.

Substantial economies have been effected in the manufacture of typewriters by standardizing machine screw body sizes and heads and by eliminating many odd shapes and lengths. Instead of using thirty different screws in a carriage, only seven are used in the same part of a new machine. The same company has also discontinued using some gauges of sheet-metal stock, and now uses as few as practicable. In these times, when it is extremely difficult to get anything but standard sheets from the mills, it is highly important that the use of odd gauges be avoided; but if their use can be avoided in abnormal times, why not always in the interests of simple stock keeping and efficient manufacture?

Bolts fitted in reamed holes rarely, if ever, require hexagon or square heads. The fit of the body in the hole should be sufficient to resist the torsion of the nut when tightening or loosening it, but the practice of using forged hexagon head bolts is general in locomotive building and repair shops. Considerable saving can be made by using round head bolts with narrow shoulders under the heads. The height of the head need not be more than three-fourths the body diameter. Bolts of this shape can be turned from bar stock when needed for quick repairs.

The Metric System and the Maintenance of Standards. F. J. MILLER. (*Proceedings of the American Metric Association,* December 28–29, 1917.)—One of the sayings which the opponents of every step in the direction of the increased use of the metric system are particularly fond of quoting is: "Measures of length are irrevocably linked to the past." This saying is attributed to one of our most prominent and honored machine-tool builders, and it is quite true in a certain sense, but not true in the sense in which it is usually employed or interpreted. It is a phrase which appeals with peculiar force to machine builders, but when it is used in arguments against the use of the metric system the literal meaning of the phrase appears to be misunderstood. The metric system can make headway, in machine construction at least, only by steps taken by those who at the time of taking such steps believe them to be advantageous from

the pecuniary point of view. Such steps are now being taken in unusual numbers for that reason.

If, instead of the saying quoted, we say, "Things made to specified dimensions so as to secure interchangeability are irrevocably linked to the past," which is generally true, and then if we recognize that these things need not be in the least changed by the adoption of the metric system, the meaning is clear. It is unwise to try to convince machine builders that our established standards of screw-threads, pipe-threads, etc., can be changed; they are admittedly "irrevocably linked to the past." The Briggs standard for pipe-threads, for instance, is now in universal use in this country. It has a taper of 0.75 inch per foot, has 11½ threads per inch, and has other dimensions specified in inch terms. Comparatively few of those who use or install pipe or fittings know or need to know what these dimensions really are; but they do know that, no matter where they may go to do a job of pipe fitting, or where they may get their supplies for the job, interchangeability is assured, and that is all they need concern themselves about; but this interchangeability is of the most vital importance, and metric opponents do not in the least overstate the case when they attempt to describe the confusion, delay, and expense that would be caused by any change in this standard.

Much the same may be said of numerous other standards, and metric advocates will do well to recognize the correctness of this attitude and to face it frankly and openly. In the metric-using shops of Continental Europe the Whitworth standard screw-threads are in general use, and those standards have been retained there along with the general use of the metric system, notwithstanding that the Whitworth thread is of English origin and has its dimensions defined in terms of the inch. It was for a long time claimed by metric opponents that the meter and the yard are incommensurable, and that any magnitude expressed in metric terms could not be exactly expressed in inch terms, but if any one were to ask the United States Bureau of Standards to verify a bar with marks upon it supposed to be one yard apart, for perfectly sound reasons, the real distance between these marks would be determined by reference to the metric bar, and the work would be more accurately done than would be possible by reference to any existing yard bar. The whole force of the opposition to the introduction of the metric system rests upon the assumption that the adoption of the metric system entails the abandonment of this or any other standard which it is worth while to preserve, an assumption which is quite useful to the anti-metric propaganda, but which is entirely without foundation in fact.

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